Vol. 1 AUGUST-SEPTEMBER, 1922 Nos. 8-9

JOURNAL

OF THE

AMERICAN WELDING SOCIETY

Published by the American Welding Society
33 West Thirty-ninth Street, New York

American Welding Society

OFFICERS FOR 1922-23

C. A. McCune, *President*
W. E. Symons, *Treasurer*
M. M. Kelly, *Acting Secretary*
Wm. Namack, *Vice-President*
T. F. Oechsle, *Vice-President*
W. A. Slack, *Vice-President*
W. Spraragen, *Editor, Journal*

DIRECTORS

Term expires 1923	*Term expires* 1924	*Term expires* 1925	*Section Representatives*
W. M. Beard	A. S. Kinsey	James Burke	T. F. Barton
A. M. Candy	J. C. Lincoln	A. F. Jenkins	R. D. Malm
C. J. Holslag	H. L. Nicholson	Hermann Lemp	Wm. Namack
P. P. Willis	E. M. T. Ryder	H. I. Walsh	E. C. Sattley
	H. R. Swartley		
	E. Vom Steeg		
	E. Wanamaker		

PAST-PRESIDENTS

C. A. Adams (1919-20)
J. H. Deppeler (1920-21)
S. W. Miller (1921-22)

CHAIRMEN, STANDING COMMITTEES

Executive—C. A. McCune
Finance—W. E. Symons
By-Laws—Hermann Lemp
Meetings and Papers—A. G. Oehler
Membership—L. B. Mackenzie

American Bureau of Welding

(RESEARCH DEPARTMENT OF SOCIETY)

OFFICERS

C. A. Adams, *Director*
H. M. Hobart, *1st Vice-Director*
A. S. Kinsey, *2nd Vice-Director*
Wm Spraragen, *Secretary*

CHAIRMEN, RESEARCH COMMITTEES

Electric Arc Welding—H. M. Hobart
Gas Welding—S. W. Miller
Welding of Storage Tanks—J. C. Lincoln
Pressure Vessels—H. L. Whittemore
Standard Tests for Welds—F. M. Farmer
Specifications for Steel to Be Welded—W. J. Beck
Welding Wire Specifications—C. A. McCune
Training of Operators—J. C. Wright
Resistance Welding—Hermann Lemp
Thermit Welding—J. H. Deppeler
Welded Rail Joint—G. K. Burgess

JOURNAL
OF THE
AMERICAN WELDING SOCIETY

Copyrighted 1922 by the American Welding Society,
33 West Thirty Ninth Street, New York.
Subscription $10.00 per year to United States. $11.00 to Canada. Libraries $5.00 Back numbers per copy, Members, $ .50; Non-Members, $1.00.
The Society is not responsible for any statement made or opinion expressed in its publications. Permission is given to reprint any article after its date of publication, provided proper credit is given.

Volume 1 Aug.-Sept., 1922. Numbers 7 & 8

TABLE OF CONTENTS

Society and Related Activities

Program Fall Meeting 3
Joint Session with A. E. R. E. A. 5
The Journal and the Welder 5
Sections of the American Welding Society 6-7
Welded Rail Joint Committee 6
Pressure Vessel Committee Organized 8
Employment Service Bulletin 11

Technical Papers, Items and Reports

President McCune's Address Before A. E. R. E. A. 12
American Bureau of Welding and Organized Research 14
Welded Rail Joints 21
Welding for the Maintenance of 1600 Street Railway Cars 25
The Use of Thermit Welding in Street Railway Shops 29
Oxy-Acetylene Welding in Street Railway Shops 32
Welding of Cast Iron 36
General Properties of Cast Iron 57
Arc Welding of Cast Iron 47
Oxy-Acetylene Welding of Cast Iron 72
Resistance Butt Welding 84
Welded Pipe Joints 94
Current Welding Literature 95

Section Officers and Headquarters

PHILADELPHIA

Engineers' Club, 1317 Spruce Street, Philadelphia, Pa.
Chairman—Theo. F. Oechsle, Consulting Engineer, David Lupton's Sons Co.
Secretary—A. Schroeder, Standard Electric Welding Company.

CHICAGO

Peoples Gas Building, Chicago
Chairman—E. Wanamaker, E. E., Chicago, Rock Island & Pacific Railroad.
Secretary—Harold W. Cook, Editor, Acetylene Journal Publishing Company.

PITTSBURGH

1841 Oliver Building, Pittsburgh
Chairman—J. D. Conway, Secretary-Treasurer, Railway Supply Manufacturers' Association.
Secretary—H. E. Hollis, P. O. Box 618, Pittsburgh, Pa.

NEW YORK

33 West Thirty-ninth Street, New York
Chairman—T. F. Barton, Master Mechanic, Delaware, Lackawanna & Western Railroad.
Secretary—A. E. Gaynor, J. A. Roebling's Sons Company.

NORTHERN NEW YORK

Niskayuna, N. Y.
Chairman—J. A. Seede, General Electric Company.
Secretary—D. H. Deyoe, General Electric Company.

CLEVELAND

Fourth Floor, Euclid Arcade Building, Cleveland.
Chairman—C. F. Eberhardt, President, Eberhardt Welding Company.
Secretary—Henry Spero, Brown Advertising Service.

SAN FRANCISCO

Rialto Building, San Francisco.
Chairman—Prof. J. C. Clark, Stanford University.
Secretary—W. B. Sawyer, Jr., United States Steel Products Company.

LOS ANGELES

724 South Spring Street, Los Angeles
Chairman—L. J. Smith, Assistant Engineer, Pacific Electric Railway Company.
Secretary—E. W. Crane, E. E., Wilson Welder & Metals Company.

BOSTON

17 King Terminal, Boston, Mass.
Chairman—Thomas A. Wry, General Electric Company, Lynn, Mass.
Secretary—J. W. Morrissey, P. F. McDonald & Co., Boston, Mass.

AMERICAN WELDING SOCIETY
ESTABLISHED 1919
JOURNAL
VOL. I. AUGUST-SEPTEMBER NOS. 8-9

FALL MEETING
AMERICAN WELDING SOCIETY
OCTOBER 2nd, 3rd, 4th and 5th, 1922
CHICAGO, ILL.

PROGRAM

MONDAY, OCTOBER 2nd, 1922

COMMITTEE MEETING

AFTERNOON SESSION — *Western Society of Engineers,* 1735 Monadnock Block.

2:00 p. m.—Committee on Specifications for Steel to be Welded, W. J. BECK, *Chairman.*

TUESDAY, OCTOBER 3rd, 1922.

COMMITTEE MEETINGS
AND
TECHNICAL SESSIONS

MORNING SESSION — *Western Society of Engineers.* 1735 Monadnock Block.

10:00 a. m.—Electric-Arc Welding Committee, H. M. HOBART, *Chairman.*

Gas Welding Committee, S. W. MILLER, *Chairman.*

AFTERNOON SESSION — *Western Society of Engineers.* 1735 Monadnock Block.

2.00 p. m.—General Properties of Cast Iron In So Far As It Affects Its Weldability,

NOTE: *Report prepared jointly by Gas, Electric & Thermit Welding Research Committees.*

TUESDAY, AFTERNOON SESSION, Continued

Gas Welding of Cast Iron,
S. W. MILLER, *Union Carbide & Carbon Research Laboratories*

Thermit Welding of Cast Iron,
J. H. DEPPELER, *Chief Engineer, Metal & Thermit Corporation*

EVENING SESSION — *Western Society of Engineers.* 1735 Monadnock Block.

8:00 p. m.—Electric-Arc Welding of Cast Iron,
WM. NAMACK, *Vice-President, Davison-Namack Foundry Company.*

(*Discussion of Above Papers*).

WEDNESDAY, OCTOBER 4th, 1922.

MORNING SESSION

10:00 a. m.—Executive Committee American Welding Society,
Office of H. W. Cook, Sec'y., Chic. Sec. Peoples Gas Building.

Committee on Training of Operators,
J. C. WRIGHT, *Chairman.*

AFTERNOON SESSION — *Western Society of Engineers.* 1735 Monadnock Block.

Joint Session American Electric Railway Engineering Association and American Welding Society.

Municipal Pier, Congress Hall, Engineering Room.

NOTE: *Guest Badge and credentials for Joint Session with the A. E. R. E. A., may be obtained at the Western Society of Engineers, 1735 Monadnock Block, Tuesday Afternoon and Evening. Be sure and get your Badge, as admission to Municipal Pier is by Badge only. (Members of the American Welding Society are also invited to attend all Sessions of the AEREA).*

NOTE: *A meeting of the Way Committee of the AEREA, at 2 o'clock, p. m., precedes the Joint Session and members are invited to attend. The Joint Session begins at 3 o'clock, p. m.*

American Welding Society and Needs for Research and Standardization,
C. A. MCCUNE, *President, American Welding Society.*

American Bureau of Welding and Organized Research,
WM. SPRARAGEN, *American Bureau of Welding.*

List of Welded Rail Joint Problems and the Work of the Welded Rail Joint Committee.
E. M. T. RYDER, *Way Engineer, Third Avenue Railway Systems.*

Applications of Welding, Electric, Gas and Thermit, in the Electric Railway Shops,
J. S. MCWHIRTER, *Supt. of Equipment, Third Avenue Railway System.*

NOTE: *All members are requested to meet at Hotel Morrison, Wednesday Evening, at 6 p. m., sharp, for a get-together dinner meeting.*

THURSDAY, OCTOBER 5th, 1922.

COMMITTEE MEETING

MORNING SESSION

Municipal Pier, Congress Hall, Engineering Room.

10:00 a. m.—Committee on Welded Rail Joints,
G. K. BURGESS, *Chairman.*

JOINT SESSION WITH THE A. E. R. E. A.

The arrangements of a joint session with the American Electric Railway Engineering Association in Chicago, during the early part of October, marks a new era in the development of cooperation in solving the welding problems of today. Our readers are already familiar with the efforts that have been made by both organizations in carrying out a program of scientific research to investigate the problems of welded rail joints. The method used by the Welded Rail Joint Committee is similar to that developed by the Division of Engineering, National Research Council and the American Bureau of Welding in solving other complex welding problems.

The possibilities of the use of welding are enormous and the savings that can be affected thereby are enormous. In joining hands with the A. E. R. E. A., we feel that a step has been made towards the scientific analysis of the application of welding in the electric railway field that will be of distinct advantage to both associations and the art.

THE JOURNAL AND THE WELDER.

In a recent article on "What Technical Foundation Should Foreman Welders Possess", appearing in our Journal, there was brought out the fact that the feeling is universal among competent authorities that if a welder is to ever advance to the foreman class he must be observant and read the current technical literature appertaining to his art.

The dues of the American Welding Society are not very great and for a slight expenditure per year, the welder is enabled to keep abreast of the latest developments in his field. Many weld-

ers do not have sufficient respect for what might be termed "book learning". They do not seem to recognize that their chiefs are often able to solve difficult problems by applying data and experience in similar problems from the technical press to their own case.

A Journal, Proceedings or trade paper should not be criticised because each issue does not contain something of vital interest to some individual. It should be recognized that if a reader finds one article that is of value to him, it is worth more than a year's dues. A question and answer column is published from time to time in the Journal of the Society through the medium of which any welder may obtain information on problems of welding on which he desires to be enlightened.

SECTIONS OF THE AMERICAN WELDING SOCIETY

On the opposite page there is shown a map of the United States, indicating the industrial centers in which sections of the American Welding Society are now actively functioning or will soon be organized. For the purpose of maintaining a close connection with local problems, the Country is divided into five Divisions, each one of which elects a Vice-President to the National Society, who is also a member of the Board of Directors. In addition, each local Section appoints a representative on the Board to serve a period of one year.

WELDED RAIL JOINTS—G. K. BURGESS, CHAIRMAN. E. M. T. RYDER, VICE-CHAIRMAN

The American Electric Railway Association, through its Committee on Way Matters, initiated the formation of a Committee on Welded Rail Joints for the purpose of having an authoritative investigation made of the various types of welded rail joints now in commercial use. The American Bureau of Welding (which is the research department on welding of the American Welding Society and the National Research Council), as the coordinating agency in the general field of welding research and standardization organized this Committee

Importance.

The statement is familiar to all that "the life of the track is the life of the joint". It is also true that the life of the pavement is the life of the track.

In not much less degree it is true, that the life of the rolling stock is dependent on the condition of the rail joints. Even the amount of traffic is in many cases effected by smooth riding track, while a noisy piece of track on a residence street has been known to keep awake not only the property owners in the vicinity, but the General Manager at a distance.

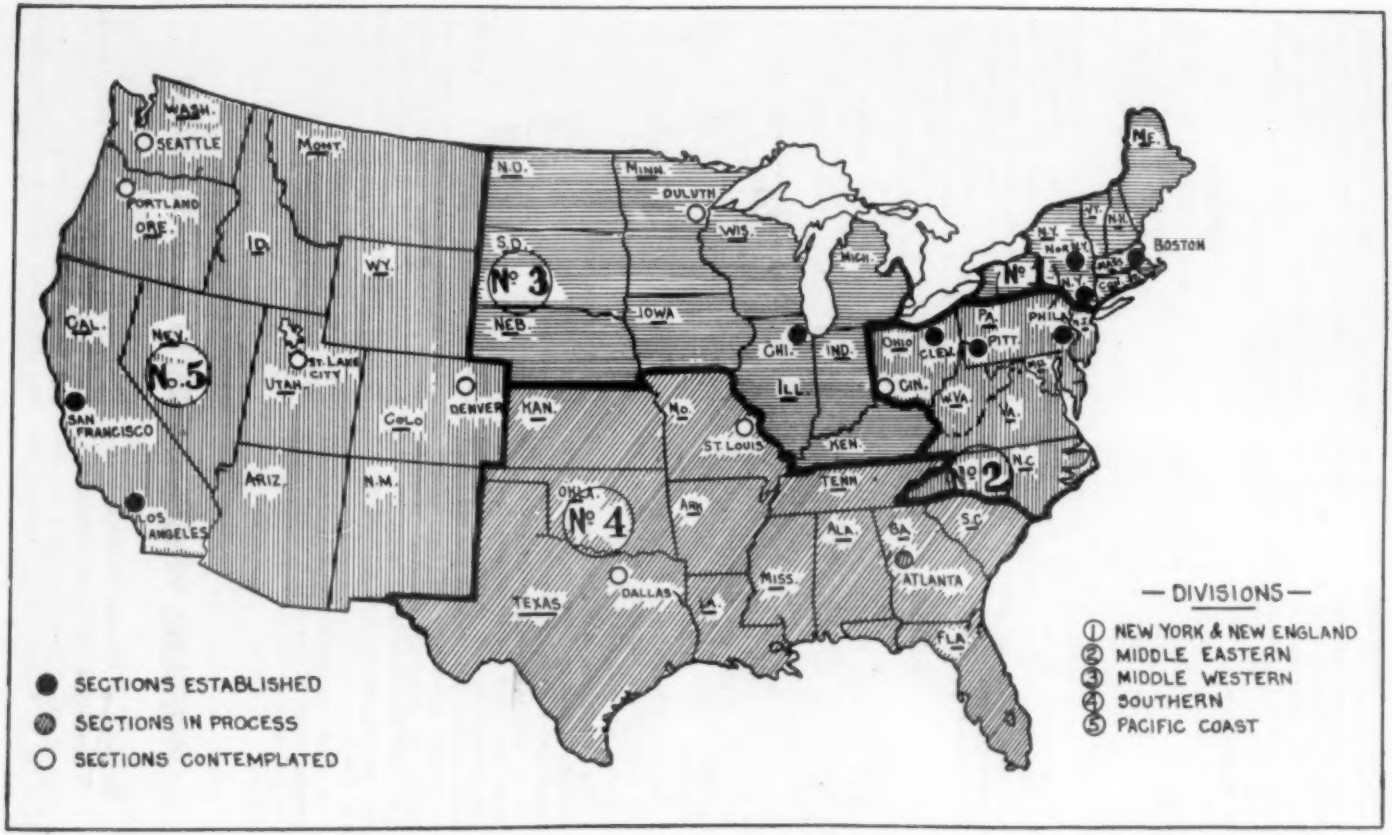
Public relations and rates of fare are by no means free from the baleful effect of bad joints in an otherwise good piece of track.

Besides the indirect value of good joints, the direct cash expenditures on account of bad joints are so great as to comprise a very large proportion of the expense of the way department.

The Welded rail joint as a general type of joint, gives promise of ultimately lessening track maintenance costs to a very great degree, but the welded joints in use today are being installed with little or no scientific data as to the correct procedure in their production, no matter what type of weld is used.

Welded Rail Joints offer large savings in the electrical and power departments. First costs of bonding are avoided and the steady drains due to waste power and low voltage are practically eliminated if the joints remain good.

Welding processes are highly technical and owing to their comparatively recent application to rail joint manufacture have not yet been thoroughly worked out. Failure to follow scientific methods may mean not only lack of complete success, but the possibility of very serious damage and expense.


WASH.
SEATTLE
PORTLAND
ORE.
MONT.
ID.
WY.
N.D.
MINN.
DULUTH
S.D.
No 3
WIS.
NEB.
IOWA
MICH.
No 1
ME.
N.Y.
VT.
N.H.
BOSTON
CAL.
NEV.
No 5
UTAH
ST. LAKE CITY
COLO.
DENVER
KAN.
MO.
ST. LOUIS
CHI.
IND.
ILL.
OHIO
CLEV.
PA.
PITT.
PHILA.
CIN.
W.VA.
VA.
KEN.
SAN FRANCISCO
ARIZ.
N.M.
OKLA.
No 4
ARK.
TENN.
No 2
N.C.
S.C.
LOS ANGELES
TEXAS
DALLAS
LA.
MISS.
ALA.
GA.
ATLANTA
FLA.
SECTIONS ESTABLISHED
SECTIONS IN PROCESS
SECTIONS CONTEMPLATED
— DIVISIONS —
1 NEW YORK & NEW ENGLAND
2 MIDDLE EASTERN
3 MIDDLE WESTERN
4 SOUTHERN
5 PACIFIC COAST

Purposes.

The general purpose of the Committee on Welded Rail Joints, is to improve the technique of manufacture of each type of welded rail joint so as to bring it to as high a state of perfection as practicable.

It is recognized that each type of joint has advantages and disadvantages. which may determine its suitability for use on certain electric railway properties. The good points should be developed and means of overcoming objectionable features should also be devised. While bearing in mind the desirability of cheapening the various joint welding processes, the main point is to insure their dependability for the longest possible period of time.

Methods.

Solution of the problems involved in welded rail joints require cooperation on a large scale. Electric Railway companies all over the country are installing thousands of joints every year, in very many cases using methods and variations in processes which have been tried elsewhere and found unsatisfactory, or the ultimate effects of which are entirely unknown.

There is a *best way* of doing anything, but with twelve big companies using ten different methods not all are right.

The Committee on Welded Rail Joints includes members from electric railway companies, rail and equipment manufacturers and technical laboratories. Its aims are: First, to determine the present state of the art; Second, to improve upon existing practices by the aid of all obtainable knowledge of the subject; Third, by carefully directed scientific tests and experiments to learn the one best way of making each type of welded rail joints.

In order to compile a Summary of the present state of the art, a questionaire was prepared on the four types of joints in commercial use and distributed to the members of the main committee. Answers to the questionaire were correlated and a progress report of 73 pages printed and distributed. Typical problems needing further investigation are also included in the report.

Budget:

The funds needed to carry out the Committee's program will be very much less than would otherwise be required, on account of the cooperation which has been offered from all sides.

The rail manufacturers will furnish rail for testing purposes. Electric Railway Companies and rail joint manufacturers will furnish joints for testing. The U. S. Bureau of Standards will supply laboratory facilities. The University of Purdue has offered to furnish ground for installing the rotary testing machine and also assistance in running it.

The following is an estimate of the funds needed for a program covering one and one-half year's time:

General Organization

Office Expenses	$3,000
Laboratory Tests	2,000
Field Tests	2,000
	$7,000

Rotary Service Test Machine

Construction and Installation	8,500
Operation	4,500
	13,000
	$20,000

The benefits to be derived from this work are such the Committee should have the backing of the entire Electric Railway Industry and if such backing is forthcoming, the cost to any one company will be an exceedingly small fraction of the savings, which result to that company.

PRESSURE VESSEL COMMITTEE ORGANIZED

Review of Events leading to Formation of Committee.

One of the major problems of the A. S. M. E Boiler Code Committee has been the formulation of rules for the construction of unfired pressure vessels. This undertaking came about as the result of an insistent demand from various states and municipalities for a code,

which would form the basis of rules governing the construction of unfired pressure vessels of various sorts. The crucial point on which a code of this sort really depends is welding. Indeed, the extensive ramifications of the kind of unfired pressure vessels which are built and the magnitude of the industries involved are such that the A. S. M. E. Boiler Code Committee has felt it necessary to proceed with extreme caution.

In March, 1920, the Council of the A. S. M. E. requested the American Welding Society to appoint a Committee to cooperate with the Boiler Code Committee of the A. S. M. E., in the preparation of that part of the code which deals with fusion welding. A tentative code based upon the opinions and experience of experts was drawn up by this Committee. With this assistance the Boiler Code Committee prepared a code covering the points which seemed to them pretty well settled, together with an appendix containing questions covering matters on which considerable differences of opinion prevailed. A public hearing was held on December 5th, 1921, at which this tentative code was reviewed. As is usual on such occasions a great variety of opinions were expressed and many other broad statements made by those who have had experience in this field. As a matter of fact, the real amount of authentic unbiased, experimental evidence contributed was small as compared with the need and importance of the problem.

Realizing the need for more complete information, based upon sound scientific investigation, the American Bureau of Welding held, a meeting for the purpose of organizing the manufacturers to deal cooperatively with the situation at hand. The need for this cooperation and benefits to be derived was brought out very strongly by Director C. A. Adams and S. W. Miller, The viewpoint of the Boiler Code Committee of the A. S. M. E. and insurance people was brought out by Dr. D. S. Jacobus and S. F. Jeter, respectively. It was the consensus of opinion of those present that an organization of this sort should be formed with the least possible delay.

The following companies have signified their willingness to cooperate in the program given below.

York Manufacturing Company
The Pfauder Company
Flyria Enameled Products Company
Union Carbon & Carbide Corporation
De La Vergne Machine Company
Coast Culvert Flume Company
Brunswick-Kroeschell Company
Vilter Maunfacturing Company

The plan proposed is briefly as follows

Each cooperating manufacturer will weld three tanks according to his standard practice of a size that will be determined by an appropriate committee. These tanks will be shipped to some central laboratory such as the Bureau of Standards and tested to destruction. A report will be published, which will include

(1.) Results of destructive tests of tanks.

(2) Results of tests of coupons taken from tanks.

(3) Complete informaion concerning the construction and details of welding (to be furnished by the manufacturer).

Such a report will be complete in itself. It may or may not be possible to draw up a code from the results obtained, but they will be a starting point. Moreover, the results may indicate which of certain practices now employed by different manufacturers are the best. It will also enable each manufacturer to know the comparative value of the products involved.

It is recognized that one of the most important things that is needed in a code for the welding of pressure vessels is specifications for a test which, when followed will insure that the vessel is reasonably safe for the purpose designed.

This information can in all probability be obtained from the investigations outlined.

Results of Meeting on August 17th

In order to carry out the above program, a Committee was organized with the following membership:

H. L. Whittemore, Chairman, Bureau of Standards.

W. Spraragen, Secretary, American Bureau of Welding.

C. A. Adams, American Bureau of Welding.

F. J. Flocke, The Vilter Manufacturing Company.

G. H. Lane, York Manufacturing Company.

S. W. Miller, Union Carbide and Carbon Research Laboratories.

W. B. Miller, The Pfaudler Company.

R. E. Wagner, General Electric Co.

L. K. Doelling, De La Vergne Machine Company.

Prof. H. L. Whittemore of the Bureau of Standards, was elected Chairman of the Committee and Mr. W. Spraragen, Secretary of the Division of Engineering, National Research Council, was appointed Secretary. The Bureau of Standards have offered its facilities for conducting destructive tests on these tanks, as well as for making physical, chemical and microscopic tests of tank material.

Mr. Obert, Secretary of the Boiler Code Committee of the A. S. M. E., stated that he was confident that the results obtained from the investigations would be of considerable assistance to the Boiler Code Committee. The size of the vessel, as agreed upon at this meeting, was a 24 in. diameter vessel, the shell of which was 6 feet without heads and was to be made of 3-8 in. stock. A data sheet was also prepared on the information which is to be furnished by the maunfacturer, relating to the methods of welding and construction used in these tanks.

The money needed for the testing is now beginning to come in and active progress is assured.

OTHER PRESSURE VESSEL MANUFACTURERS ARE URGED TO PARTICIPATE IN THE ABOVE WORK. IF YOU ARE INTERESTED, WRITE TO

AMERICAN BUREAU OF WELDING
33 WEST 39th STREET
NEW YORK CITY

EMPLOYMENT SERVICE BULLETIN

To meet the demand of its members, the American Welding Society maintains an Employment Service Bulletin. This service particularly needed in the present business readjustment. The bulletin is divided into two sections —POSITIONS VACANT and SERVICES AVAILABLE. No charge will be made either to the available engineer, foreman or welder, or to the organization seeking welding talent. The number of opportunities for employment of which the Society has knowledge does not at present equal the number of men whose services are available. The cooperation of members of the Society, industrial establishments and others needing the services of men trained in the various branches of welding is earnestly desired. The fact that an applicant for a particular position reads the Journal of the American Welding Society shows an honest effort on his part to keep abreast of the latest advancements in his chosen field. The location, necessary qualifications for each position and the approximate salary, if possible, should be stated in each case.

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the bulletin.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's office not later than the Thirteenth of the month if publication in the following issue is desired. *ALL REPLIES should be Addressed to the Number Indicated in Each Case and Mailed to Society Headquarters.*

POSITION VACANT

V-7.—WANTED. A first-class electric welder for service in Mexico. We need a man who can do overhead electric welding in locomotive fire box work in our railroad shops at Monterey. Will pay $250.00 per month at start, which would be raised to $300.00 after six months satisfactory service. A good, steady reliable man is needed who will not hesitate to prepare his own work if necessary. On heavy jobs the work is prepared for welder. Room and board can be obtained at about $60.00 per month and up New York office will make arrangements for transportation.

POSITION AVAILABLE

A-6—WELDER. Age 31, married, desires position. Three years experience in marine boiler repairs, tanks, cast iron, brass, manganese, etc., with electric arc Have also a fair working knowledge of acetylene welding. Have been employed for past two and one-half years with Staten Island Shipbuilding Company.

A-10. ELECTRIC WELDER desires position. Have had six years experience at locomotive shop, round house and marine boiler welding. Worked for the Standard Oil Company, of Indiana, for five years.

A-11. MECHANICAL ENGINEER: Stevens graduate, B Member of the A.W.S. and Junior Member of the A.S.M.E., with several years of executive service, engineering experience with a large welding supply company, experience in handling practical welders, together with practical business training, is open for an offer from a welding or welding supply company. Services available, October 1st.

ADDRESS TO THE AMERICAN ELECTRIC RAILWAY ENGINEERING ASSOCIATION *

C. A. McCUNE †

Gentlemen:

The American Welding Society is indeed honored to meet in a joint session with the A. E. R. E. A. at this your 41st annual convention. The achievements of your association are universally recognized and the findings of your technical committees received with profound respect. You have set an example well worth following and we appreciate this opportunity of contributing our testimony in this official manner.

In comparison to your Association, the American Welding Society in years, is a very young organization, but already we have accomplished a great work and our Standards are fast being accepted throughout the industrial world.

The problems that confront the Street Railway Engineers are many and varied as well as interesting and from observations of your proceedings as well as close contact with the individual Street Railway Companies, we know that welding ranks high among those problems that can be classed as interesting.

The benefits derived from your valued cooperation and this joint session are bound, therefore, to result mutually. The American Welding Society differs from most technical bodies in that it is devoting all its energy to a single art, that of welding; its membership comprising many of the best minds in welding engineering, gas, mechanical, electrical, civil and marine engineering, chemistry and metallurgy.

The American Welding Society is organized to provide united and cooperative action in extending the knowledge of the art of welding by every recognized process and its field of industrial application. This is accomplished through three distinct channels, namely, society activities, American Bureau of Welding and the society Journal.

Society Activities

Sections of the American Welding Society are now organized in nine leading industrial centers, (from Boston to San Francisco, inclusive); others will also be established throughout the country to provide a common ground for the investigation and discussion of welding problems to eliminate costly duplication of work and for the general promotion of the art and the work of the Society. Regular monthly meetings are held in each section at which papers

*To be presented at joint session of the A. W. S. and the American Electric Railway Engineering Association, Chicago, Oct. 4, 1922

†President American Welding Society.

and lectures of general interest are presented and discussed. An oportunity is created for the exchange of ideas between the welder and the engineer and those generally responsible for results. Means are thus established for mutual cooperation, assistance and advancement all of which contribute to efficiency.

American Bureau of Welding

You appreciate the value of standardization and that scientific facts must govern the operation and construction of every part of your equipment. This is equally true in welding where many of the problems are of such a nature that involves many variables. It is one thing to obtain a result and quite a different thing to know the reason why the result is obtained and to consistently repeat it. In the majority, satisfactory results have been obtained in welding, but when failures have occurred, the reason why was not always known.

To bring about coordination of effort to arrive at standards and for the purpose of investigating welding problems, there was organized by the American Welding Society and the Division of Engineers of the National Research Council, an Advisory Committee on Welding Research and Standardization, known as the American Bureau of Welding. The Bureau is therefore the research department of the society. It is made up of representatives selected from the Society, one representative each from approximately twenty other interested scientific engineering and classification societies and government bureaus. (Mr. E. M. T. Ryder is the representative on the Bureau of the American Electric Railway Association.) In addition, there are certain members at large appointed, because of special fitness.

The details of the functions of the Bureau, its methods of operation; the advantages of organized research and the accomplishments, will be presented to you by Mr. W. Spraragen, the Secretary of the American Bureau of Welding and also Division of Engineering, National Research Council.

Apart from specific research results, the American Bureau of Welding will fill the long-felt need for a national unbiased authority on the art.

Journal of the American Welding Society

The means of communication with its membership and the industrial world is established by the Society, through the medium of its Journal, a monthly publication distributed free to every member of the Society. The Journal enables the members to keep abreast with the latest developments in welding, the progress made by the various research committees of the Bureau, findings of these committees, the news of local sections, employment opportunities, current welding literature, standardization work, important papers delivered at local sections, offerings of manufacturers of apparatus

and supplies, solution of difficult welding problems, etc.

Conclusions

I have tried in this brief review to present a general outline of the aims of our Society and to call to your attention that every available scientific and practical means are adopted to invite full confidence, throughout the industrial world in the welding process, the operator, equipment and welding materials. I am confident that at the conclusion of this joint session, we will be in complete accord and it is our sincere hope that this first meeting will only be a forerunner of many more to come.

In closing, I again thank you in the name of the American Welding Society for this excellent opportunity of being with you and I extend to every member of the A. E. R. E. A., a very earnest and cordial invitation to attend the meetings of the Society of the American Bureau of Welding, so that you may sit with us and see the work we are doing and possibly as individuals become members of our organization and join closer with us, for a thoroughly united effort throughout the entire industry.

THE AMERICAN BUREAU OF WELDING AND ORGANIZED RESEARCH *

W. SPRARAGEN †

President McCune has told you that the American Bureau of Welding is a joint advisory committee of the American Welding Society and the Division of Engineering, National Research Council. It acts as the research department of the American Welding Society.

National Research Council

National Research Council is a cooperative organization of American societies concerned with the physical, mathematical and biological sciences and their applications to human welfare through the agricultural, engineering and medical arts. Approximately eight societies are included. Among the Council's members are also business men interested in the industries. The Council was organized in 1916 under the charter of the National Academy of Sciences to coordinate the research facilities of the country for work on war problems. In 1918, by executive order of the President of the United States, it was reorganized as a permanent body for the promotion of research in the natural sciences and of the application and dissemination of scientific knowledge for the na-

*Paper to be presented at joint session of the A. W. S. and American Electric Railway Engineering Association, Chicago, Oct. 4, 1922.

†Secretary American Bureau of Welding and Division of Engineering National Research Council.

tional well being. By this order, the departments of the Government are directed to cooperate with the Council; but notwithstanding close and cordial relations with the Government, the Council is not a governmental bureau.

Financial support is assured in part by a gift of $5,000,000 made by the Carnegie Corporation in Dec., 1919, of which $1,350,000 is being devoted to the erection of a building in Washington for the joint use of the Council and the National Academy of Sciences. The remainder is to serve as an endowment, the income of which is to be applied to expenses of the Council.

The Division of Engineering, one of the thirteen Divisions of the Council aims to carry out the general purpose of the National Research Council in the field of engineering by stimulating research and coordinating the work of existing agencies. It seeks to minimize duplication wherever it is wasteful, to concentrate scattered efforts, to promote progress, to suggest programs for projects, but not in any case to dictate procedure, to encourage individual initiative and to make knowledge gained more widely accessible.

The Division of Engineering with the assistance of an advisory committee or board in each broad field of engineering, plans programs for the projects brought to it or proposed by it, aids in organizing the interested group, finds men and means for carrying out the plans, coordinates the work of societies, industries, governmental bureaus, universities and individuals and in general stimulates research on the problems selected. Work on each problem is conducted under the supervision of a research committee led by a chairman who is a recognized expert. Modes of handling projects differ according to their nature, the funds, facilities and workers available and the geographic distribution of the group interested. Results are published in the Journal of the engineering society most vitally interested, which in the case of welding, is the Journal of the American Welding Society, or in an appropriate technical periodical, or in a Bulletin of the Council.

Organized Research

That stage of world's development in which mankind could depend solely on individual geniuses for advance has been passed The modern method is more rapid, surer of its path and more likely to succeed. There are brought to bear on the problems of the constructive professions and the industries, the combined wisdom of numbers, the accumulated knowledge and the skill of scientist and engineer; of practical man and theorist and consideration is given to the viewpoints of manager, owner, worker and consumer. Cooperation and coordination in the field of engineering research, are being effected progressively by the Division of Engineering, National Research Council, with the aid of the Engineering Foundation and the Engineering Societies. In the field of welding, this

coordinating body is the American Bureau of Welding, which is the joint advisory committee of the American Welding Society and the Division on welding research and standardization.

American Bureau of Welding*

The American Bureau of Welding is organized to foster the improvement of welding methods, material and equipment and to establish codes and standards. Professor C. A. Adams is Director. Eleven research committees are working on problems, the nature and importance of which are indicated by the titles; Electric Arc Welding, Welding of Storage Tanks, Welding Wire Specifications, Standard Tests and Welds, Training of Operators, Specifications for Steel to be Welded, Resistance Welding, Thermit Welding, Welded Rail Joints, Welding of Pressure Vessels, The present status of each of these committees is given as Appendix A.

Method Developed by the Bureau

Having selected a specific problem for consideration a small number of experts are called together for a preliminary conference to draw up a suitable statement of the problem, its importance and probable value of its solution. Members of a Committee are then selected representative of the interested industry or branch of the Profession and the related sciences, technical societies, governmental bureaus or educational institutions.

Procedure may then develop somewhat as follows:

(a) Preparation of a bibliography and critical summary of our present knowledge, including the gathering of all available experience. These summaries serve the two-fold purpose of giving a concise statement of the best existing information and enabling the Committee to draw up more intelligently a program of needed research to obtain data that are lacking.

(b) Consideration of the summary and laying out of specific tests, inquiries or experiments. Often standardization of nomenclature and of methods of testing is necessary before effective progress can be made with the actual research. (Improvement of nomenclature or of testing methods and apparatus is in some cases one of the most valuable results accomplished). Care is taken to select the more urgent or promising features of the project for the first attack and not to attempt more than there is reasonable probability of handling.

(c) Assignment of definite portions of the program to appropriate laboratories, sub-committees, companies or individuals.

(d) Stimulation of research in this field as may be fitting, by individuals, governmental bureaus, corporations or universities. To this and a list of research subjects may be compiled and published.

*Write to the Secretary for a Pamphlet of the Division of Engineering of National Research Council and the American Bureau of Welding.

If a large committee is advantageous frequent meetings are not attempted; ordinary business is conducted by a small executive committee. Specific tasks are handled by individuals or by appropriate sub-committees which can meet or correspond as necessary. Progress is accelerated wherever practicable by the employment of men having the requisite qualifications. As the work proceeds progress reports and papers are presented to the American Welding Society. At the completion of each task, a final report is submitted.

Accomplishments

Although organized for a comparatively short time the following report have been published.

"Welding Mild Steel", by Henry M. Hobart, presented at a joint session of the American Institute of Electrical Engineers and American Institute of Mining and Metallurgical Engineers, February, 1919. Results of an elaborate series of investigations conducted during the War under the auspices of the National Research Council and Emergency Fleet Corporation.

"Speed of Metallic Arc Welding", by Wm. Spraragen, in "Welding Engineer", June, 1920.

"Standards for Testing Welds", (report of committee), Bulletin No. 1, of American Welding Society.

"Welding Wire Specifications", (report of committee), Bulletin No. 2, American Welding Society.

"Standards for Arc Welding Machines", (report of committee), Bulletin No 3, American Welding Society.

Pamphlet entitled, "American Bureau of Welding", November, 1921.

"Resistance-Welding Nomenclature", (report of committee), July, 1922, Journal of American Welding Society.

"Present State of Art of Electric Percussive Welding", by D. F. Miner, Journal of American Welding Society, July, 1922.

"Progress Report, No. 1.—Present State of Art in Making Welded Rail Joints", a 73-page bulletin complied by Welded Rail Joint Committee.

"Tentative Code; Welding of Unfired Pressure Vessels", report of Welding Conference Committee, submitted to Boiler Code Committee, of American Society of Mechanical Engineers, December, 1921.

"Present state of the Art of Butt Welding", (report of committee), Journal of American Welding Society, August-September, 1922.

"Present state of the art of Welding Cast Iron", Journal American Welding Society, August-September, 1922.

Other reports have been finished and will be published shortly.

APPENDIX A.

Present Status of Research Committees of the American Bureau of Welding

Electric Arc Welding,—H. M. HOBART, *Chairman*

Rules have been compiled, covering Standards for Electric Arc Welding Apparatus, which provide Standards for use in connection with specifications for the purchase, sale and use of such apparatus.

The rules include, classification, definition of terms, information relative to apparatus to be supplied by the manufacturers and by the prospective purchaser respectively and tests for determining the fairness of rating.

A summary on the Electric Arc Welding of Cast Iron has just been completed. This summary will serve the two-fold purpose of giving the industry a concise statement of best existing information and enabling the Committee to draw up intelligently a program of needed research to obtain data that are lacking.

A comprehensive report of the present state of the art of the application of electric arc welding to Shipbuilding, is well under way and will probably be finished within a few months. Developments of application of arc welding to steel and non-ferrous metals are receiving consideration.

Gas Welding—S. W. MILLER, *Chairman*

The attention of the Committee during the past year has been confined to drawing up Summaries of the present state of the art of welding of pipes and cast iron. The latter report has been finished and is published in this issue.

This Committee has rendered considerable aid to other Committees such as Training of Operators, Welding of Storage Tanks and Welding Wire Specifications, insofar as the problems of these Committees relate to Gas Welding.

Resistance Welding—H. LEMP, *Chairman*

Several reports setting forth the present state of the art are in preparation. Of these, reports on Nomenclature, Butt Welding, Percussive Welding and Seam Welding have been completed and published in the Journal of the American Welding Society. Sub-Committees are also at work on Summaries dealing with Spot Welding and Standardization of Resistance Welding Transformers. A list of several subjects worthy of research has been prepared.

Thermit Welding—J. H. DEPPELER, *Chairman*

Researches which will bring about improvement in quality of thermit welds and reduction of cost, are being carried out by the Metal & Thermit Corporation. This Committee is cooperating with the Committee on Welded Rail Joints in certain investigations.

Standard Tests for Welds—F. M. FARMER, *Chairman*

Standardization of procedure in making a test of any kind is obviously necessary before results obtained by different observers can be compared. Difference in detail of procedure in testing welded specimens has caused widely divergent results. Comparisons are frequently impossible, consequently, the usefulness of much of the research work as recorded is restricted and in many cases the statements of results are actually misleading. The Committee has drawn specifications for Standard Tests of Welds, now universally used in this country and which is also receiving the attention of scientists abroad.

Welding Wire Specifications—C. A. MCCUNE, *Chairman*

Several years ago, the notion prevailed that almost any fence wire was good enough for welding and although satisfactory results were sometimes obtained, it is now recognized that the most careful consideration must be given to the physical as well as to the chemical characteristics of the welding wire, if good results are to be assured.

During the greater part of the past two years, the Welding Wire Specifications Committee has been actively engaged in collecting data as to the chemical analysis of welding wire used for both gas and electric welding in railroads, shipyards and other places and the service results obtained in the use of such wire. Specifications based upon this information have been drawn and published.

Tests other than of chemical composition for distinguishing between good and bad welding wire, are under consideration. These methods are, (1), heating electrically to fusion, (2), heating by oxy-acetylene to fusion. The theory of these tests is similar to that given for distinguishing between weldable and unweldable qualities in steel as indicated below.

Specifications for Steel to be Welded—W. J. BECK, *Chairman*

Experiments are under way in the plants of four or five companies to investigate several methods which have been proposed for distinguishing between suitable and unsuitable material to be welded. The different methods employed in these experiments are:

1. Heating electrically to fusion.
2. Heating by Oxy-Acetylene torch to fusion.
3. Heating on a vitreous enamel by heating electrically.

In all cases the criterion is that suitable materials are well degasified and fuse quickly, while unsuitable materials are largely those not degasified, or only partially and therefore, fuse with gas evolution and more or less effervescence, sparking, bubbing and spattering. Materials for these tests are being furnished by steel manufacturers.

Training of Operators—J. C. WRIGHT, *Chairman*

A report is in preparation covering the qualifications for welders, fundamentals of welding, analysis of welding jobs and bibliography of welding. The work of this Committee is being conducted in cooperation with the Federal Board of Vocational Education, of which organization the chairman is Director.

Welding of Storage Tanks—J. C. LINCOLN, *Chairman*

This Committee was organized to meet the requests for information from the Standard Oil Company as to the proper procedure for welding tanks for holding light oils. Considerable difficulty has been experienced in the riveted tank, because such structures in practice do not prove to be "oil tight" for the lighter oils.

The result of this application of Welding promises not only a cheaper, but also a better storage tank and will open up a new and large field to which welding is particularly adapted. Several small tanks have already been built successfully in this way, although the designs were not specially adapted to welding.

Specifications for the electric and Oxy-Acetylene welding of a tank 40 to 50 feet in diameter and 25 feet high, have been completed. The Standard Oil Company has agreed to construct one of these tanks by welding.

Welding of Pressure Vessels—H. L. WHITTEMORE, *Chairman*

AND

Welded Rail Joints—DR. G. K. BURGESS, *Chairman*

A complete report of these two committees is given elsewhere in this Journal.

WELDED RAIL JOINTS *

E. M. T. RYDER †

INTRODUCTION

The subject of Welded Rail Joints is by no means a new one, but it has certain aspects which we usually associate with new problems, namely the features of novelty and uncertainty.

As variety is still the spice of life, Way Engineers find the subject fascinating in itself aside from the promise it gives of substantially solving one of our most serious track problems.

It also carries a lurking danger in the allurement it offers for experimentation on a large scale, with the ultimate expense unknown.

In dealing with welded rail joints, some of us are inevitably reminded of the "little girl who had a little curl, etc.," for there is no doubt that "when a welded joint is good, it is very, very good, but when it is bad, it is horrid."

Some Engineers are even yet unconvinced of the wisdom of "burning their ships behind them" and trusting themselves to build new track, or rebuild old, with welded joints and without the comfortable feeling that there are at least a half dozen good one-inch bolts in each joint trying to keep some evil agency from making them work "loose."

Let us assume that there is some truth in the idea that we are lost in the welded rail joint woods. What should we do?

In such circumstances there are three things to consider:
First: Where did we come from?
Second: Where are we now?
Third: Where should we go?

HISTORY

Answering the first question it can be truthfully said that we have come a long way, farther perhaps than we realize. Welded joints have been in the field since the beginning of the electrirc railway industry.

Falk Cast Weld Joints were in use before the horse cars disappeared. Lorain Bar Welds were being tried out nearly thirty years ago.

Perhaps a brief glance at the development of the principle types of joints may be interesting.

CAST WELDS

Joints of this type were installed in 1890 in Brooklyn on old rail and in 1894 in St. Louis on new rail. An old Falk Company catalogue shows that they installed cast weld joints in rail from

*To be presented at joint session of A. W. S. and the American Electric Railway Engineering Association, Chicago, Oct. 4, 1922.

†Way Engineer, Third Avenue Railway System, New York City. Vice-Chairman, Welded Rail Joint Committee.

9 in. high, down to 3 in., (the latter in Oakland, California, in 1896) and that 500,000 joints were installed in five years.

Resistance Welds

To the Lorain Steel Company and its predecessor, the Johnson Company, is due the credit of making a commercial success of this type of joint, the pioneer work having been done in 1894.

The bar weld which was their standard for many years, consisted in welding a flat bar on each side of the web of the rails to be joined, the actual welds being located at the ends and in the center of the bar.

This process has been improved within the last half dozen years by the addition of a chock block welded under the heads of the rails directly at the joint and also welded to the webs of the rails and to the main welding bar. Some 800,000 bar welds have been installed to date.

The Lorain Steel Company is now also installing a "Butt" weld under the Jacobs patents, upwards of a thousand of these joints having been put in during the past year.

The process welds the entire cross-section of the rail ends, leaving a finished joint hardly differing from the rail itself in size by more than the thickness of a lead pencil.

Seam Welds

When trolley lines were first built, the use of a sewing machine to make rail joints would hardly have regarded less visionary than to make a "seam" between rail and joint plate by using an electric current and a carbon or steel pencil, but the magic of the electric arc is now responsible for the making of seam welds by thousands on electric railway properties all over the country. Some welds were first developed on a commercial scale in Germany and were introduced into this country in 1914 by the Atlantic Welding Company. However, four years before that date, joints designed by Mr. C. F. Gailor had been installed in track on Main St., Hartford, Conn., using acetylene gas to make the welds, these joints lasting in sound condition until the track was reconstructed in 1918.

The Atlantic Welding Company in their first work in New York City used double refined iron plates, Swedish iron rods and a semi-automatic control for the electrode holders obtaining current from imported motor generator sets weighing five tons. Changes were gradually made to the methods now in use, using steel plates and rods and hand control for the electrodes, with generating apparatus light enough to be moved about by two or three men. The resistance method of stepping down trolley voltage is also in use and both metallic and carbon electrodes have their advocates.

In describing present conditions, one may use various terms according to his convictions, or his nerve. If not pessimistic enough to say chaotic or embryonic, he might be contented with experimental or developmental.

An impartial observer could hardly say that we have reached "normalcy."

THERMIT WELDS

Now-a-days chemistry is so interwoven with all our actions that we do not stop to think where that science ends and others begin.

Making a rail joint in a chemist's test tube might be said to have become an actuality in the case of the Thermit joints.

Thermit joints like Seam Welded joints were developed in Germany, reaching commercial proportions about 1902. In these joints the rail ends were butted together, heated by the Thermit metal and then forced together by clamps. The only present modification in European practice consists in using a copper coated steel plate between rail heads which is thought to increase weldability.

Thermit welding was introduced into the United States in 1904 and has had three principle stages of development.

The method at first used gave a weld of the base and web of the rail only.

In the second method, the rails were separated, the Thermit casting filling the entire space and forming part of the running surface of the rail. The present method introduced ten years ago is based on inserting a head shim of rail steel to form the running surface, the Thermit steel welding the rest of the section, including in girder rails the lip and the outside of the head. Recent improvements have cut down the amount of Thermit metal and of manual labor required while at the same time increasing the reliability of the process.

PRESENT CONDITIONS

Our second question in the welded rail joint woods is: Where are we now? Let us answer this question by asking some others. Have we taken our bearings carefully? Are we on the right track? Do we know how to make each type of rail joint the very best way? Are all the metallurgical problems settled? Can we control the processes so as to always get good joints and never bad ones? Must we not admit that we are compelled to answer many of these questions in the negative?

Progress Report Number One of the Committee on Welded Rail Joints throws some light on these questions.

Looking through the replies for Cast Iron Welds, we find the following: (the classification numbers being used for reference purposes.)

112.1 Weight of Joint Castings:

Smith: 100 lbs., Wilson: 170 lbs. Cram: 200 lbs., Kerwin: 235 lbs.

Agreement on such a foundamental as the size of the casting is certainly not complete.

180.1 When do cast welds fail?

Cram: "Failures are principally due to *slips*."

Kerwin: "About 15 per cent of joints show breakage of *head of rail* over weld after twelve or more years of service."

Smith: "The greatest number of failures are in the *casting*."

Wilson: "Most failures occur by *rail splitting* at top of web directly under the head."

The doctors do not even agree as to the cause of the demise.

Picking out one item in the report for Resistance Welds, it is amusing to note the answers to the query 232.12: Use of expansion rails in closed track.

George: "No." Punderford: "Yes." Kleinschmidt: "No." Steward: "Yes."

For electric seam welds there were more replies to the inquiry schedules than for any other type of joint and there was more variation in practice and in opinion.

The practice of some companies is to weld seams for the full length of the plates; on the other hand, some companies do not weld seams all the way to the ends and some do not weld seams at the center of the plates.

Beveling the top of the plates is practiced by many, but considered unnecessary by others.

Base plates are not generally used, but have some enthusiastic advocates.

As to using inserts or shims, some use them freely, some not at all. Many allow a single shim as an unavoidable evil; while one reply advises using more than one and one man prefers to melt down his rail ends and build them up again.

In the matter of heat treatment, a few companies preheat the joints before welding and one post heats, but the majority do neither.

It is only fair to the Way Engineers to say that the manufacturers of joint welding equipment are themselves not in a position to give authoritative information on a great many of the moot points in the welding art.

The fact is that for all types of rail joints, our knowledge of the physical, chemical and metallurgical problems involved is altogether inadequate.

From the Engineering point of view we do not know either the loads applied to the structure or its powers of resistance.

With any of the different types, we can make joints which look good when they are new. What will be the effect of rail wear, of the hammer blows of traffic, of temperature strains, of repeated bending, of corrosion, of time itself?

What we want to know is how to make joints that will last as long as the rail.

We do not know that now.

Future Development

This brings us to our third question: Where should we go? Where, but to Science and Cooperation, two of the most powerful factors in the world's progress today! Many of us are attacking these problems independently, which inevitably means duplication of effort and probably means very slow and uneven progress.

Scientific study of such complicated problems as exist in the

production of welded rail joints can be undertaken to advantage only under expert direction and with adequate resources.

Both of these requirements seem in a fair way to be met by the organization of the Committee on Welded Rail Joints.

Its membership comprises Experts of the U. S. Bureau of Standards, Perdue University and other technical laboratories, together with Representatives of Rail and Equipment Manufacturers and Way Engineers from many of our principal Electric Railway Systems.

The Committee should have the backing of the entire Electric Railway Industry.

WELDING FOR THE MAINTENANCE OF 1600 STREET RAILWAY CARS *

By J. S. McWHIRTER

Superintendent of Equipment and Buildings, Third Avenue Railway System, New York, N. Y.

The American Welding Society has requested that I tell you something of welding as we have found it from our experience on the Third Avenue Railway System of New York.

In order that you may understand something of our conditions, I will say that the Third Avenue Railway operates approximately 1600 cars in the City of New York and in several of the adjoining municipalities. Forty-six per cent of the cars operated by the underground conduit system, forty-nine per cent by overhead trolley and the remaining five per cent by storage battery. Overhauling, reconstruction and all but minor repairs are done at a central repair shop located at 65th Street and Third Avenue, in the Borough of Manhattan. This centralization of overhauling and maintenance has simplified our requirements for welding facilities.

We started electric welding in 1915, using the carbon arc with graphite electrodes, the current being obtained from the 600-volt railway circuit by stepping down the voltage through second hand car resistances. At present we are doing forty per cent of our welding with the graphite electrode, fifty-five per cent with the metallic electrode and five per cent with the oxy-acetylene torch. Our equipment consists of five constant energy, 200-ampere, individual motor generator sets and two constant potential motor generator sets, one of 300-ampere rating and one of 400-ampere rating. There are still in use two banks of resistences fed by the

*To be presented at joint session of A. W. S. and American Electric Railway Engineering Association, Chicago, Oct. 4, 1922.

railway circuit, but we are planning to replace these resistances as fast as the development of the art and operating economy justify the change. Our leaning is towards individual motor generator sets because of the superior regulation of the arc which is obtained with the individual set as compared with the larger motor generators.

We have one oxy-acetylene welder. The greater part of his time is spent in repairing bronze armature bearings, bronze brushholders and other bronze parts. We find it more practicable to use the oxy-acetylene torch on bronze than the electric arc, because of the objectionable fumes which result when bronze is welded with the arc. The oxy-acetylene operator also does all but the roughest cutting and the few steel welds which are inaccessible to our electric arc welders. But we prefer the electric arc for the welding of the average truck or car body part, the electric arc in our case doing the work at about two-thirds the cost of the oxy-acetylene torch.

The foregoing briefly outlines our development. You will note that we started electric welding with the graphite electrode and that we have gradually changed over toward the metallic electrode. Our only reason for continuing the use of the graphite electrode is the speed with which metal can be deposited, but this advantage is limited by the requirement that the graphite electrode must not be used where the welded part will be subject to stress.

Our organization consists of one foreman, who devotes about sixty per cent of his time to other work, one semi-automatic welding machine operator, four metallic electrode welders, two carbon arc welders and the one oxy-acetylene welder. With this organization we are able to do all the welding that is necessary for the maintenance of our 1600 cars and a normal amount of reconstruction. I might amplify this statement by saying that this organization will take care of all the welding which we believe is economical to undertake. It is our experience that welding is not justified in all cases where surface indications point to its use.

The volume of work turned out by our welding organization is best measured by the pounds of welding metal used per year, which runs with us about 25,000 pounds of bare soft steel welding and 1500 pounds of manganese bronze. The average amount of metal used per operator with our three types of welding is as follows: with the metallic electrode, 1.2 pounds per man per hour, with the graphite electrode 1.6 pounds per man per hour and with the oxy-acetylene torch, 0.6 pounds per man per hour.

Our biggest routine welding job is the rebuilding of worn axle bearing seats on cast steel motor shells of sixty-five horse power motors. We weld two of these shells a day, one operator hand welding with 3-16 inch metallic electrodes and one operator working with ⅛ inch metallic electrodes fed by the semi-automatic

welding machine. We would prefer to do this job with the full automatic welding machine, but the concave surfaces of the axle bearing seats do not permit the use of the full automatic. While our results to date have been satisfactory, it is to be noted that the hand operator accomplishes as much work per day as the man using the semi-automatic. But the hand work welder is working close to the limit of hand welding capacity to accomplish this result, while we contemplate increasing the capacity of the semi-automatic machine by thirty per cent.

The welding and reinforcing of cast steel and forged truck frames and of cast steel motor frames has been practiced since 1908. In 1908 and 1909, a large number of these were welded by the old Goldschmitt-Thermit company under contract and these welds have given satisfactory service. When we started electric welding, we welded these parts with the graphite electrode, but the breakages were excessive. We now weld them with ⅜ inch metallic electrodes and secure very satisfactory results. It is our opinion that it is cheaper for us to use the metallic electrode process for this work than the thermit process.

The welding of gear cases has proved very economical. Our annual saving on gear cases alone is about $12,000. While the majority of our gear cases are of malleable iron, we are able to do a fairly satisfactory welding job on patches and reinforcing pieces by using a good grade of coated metallic electrode. We do not depend upon these welds for strength.

We have had some experience welding axles. When the automamatic welding machine was first developed we installed one on a second-hand lathe and started it welding worn driver axle bearing seats. The deposited metal was laid on in the form of a screw thread as the axle revolved in the lathe. This part of the work was very economical, as the nine hour welding job required but one hour of a man's attention.

These axles were AEREA, standard Number E-A and up to the time that we started welding had never broken in service. A careful record was kept of all welded axles and without exception the welded axles broke through the welds after six to nine months' service. In some cases this was due to faulty welding; a fault not of the welding machine, but rather of inadequate control between the lathe feed and the automatic welding feed. But the majority of the breakages were through perfect welds.

Investigation of the cause of these breakages show it to be due to the quenching action of the mass of the axle upon the surface of the axle subject to the heat of the arc, the result being a hard and brittle layer of metal surrounding the axle immediately under the soft deposited metal. Investigation further showed that this hard layer could be successfully removed by annealing the welded

axle under close temperature control. But after the axle was annealed it was necessary to straighten out the warpage caused by the annealing and to true the bearing surface in a lathe. When the cost of the labor, material, electric current and equipment required to reclaim the axle, was totalled, it was found that the saving was only about twenty per cent of the final cost of a new axle.

We reclaim a large number of brake shoe heads, brake beams, side and center bearings, journal boxes, step hangers and other truck and car body parts. We estimate our annual net saving on these parts to be about $45,000.00. This saving is after deduction of other shop labor on the reclaimed material and the deduction of a liberal allowance for maintenance, depreciation and fixed charges on the welding equipment, wages of foremen and clerks, superintendence, building rental and our other items of overhead.

To secure the maximum benefit from the reclaiming of truck and car body parts it is necessary that all parts which are to be welded be made of cast steel or forgings, in place of the malleable iron which is so common in electric railway car equipment.

Our experience with welding malleable iron has been that while it is possible and often necessary to weld this material, the welds do not possess sufficient strength to justify the welding on a large scale.

The advantages of welding for emergency repairs are well known. A single instance of our experience will illustrate this point. One afternoon the four foot cast iron fly-wheel of the paper cutter at our printing plant was broken, thus completely tying up the printing of our transfers, no replacement part being available, short of a six weeks delivery. By reinforcing the wheel with steel plate, liberally studding and working half the night, we were able to have the paper cutter in operation the next morning. This repair has now been in constant service over two years without a failure.

In a paper of this kind, there is very little room for a discussion of the technical features involved, but those who are interested will find a clear statement of the physical changes produced in steel by welding in the very able paper, which was presented before the Chicago Section of the American Welding Society in 1920, by Mr. T. D. Sedwick, Engineer of Tests, Rock Island Lines. Mr. Sedwick takes up the question of pre-heating and annealing in detail. And our experience has been in line with his conclusions.

In conclusion, it must be said that electric welding proved a life saver to us during the war periods of inflated prices and slow deliveries. We undoubtedly did a large amount of welding in those periods which would not be justified today, but it is a tremendous benefit to the electric railway industry to have available welding facilities which will take care of such emergencies.

THE USE OF THERMIT WELDING IN STREET RAILWAY SHOPS *

J. H. DEPPELER †

Thermit welding is used extensively for reducing maintenance costs in street railway shops throughout the country in making up special work, welding arms to broken mates, welding compromise joints when needed and for repairing car truck frames, electric motor cases and for other useful purposes too numerous to be mentioned.

Making Special Work by Means of Thermit Welding

One of the most striking developments of Thermit welding has been the remarkable spread of this process for welding sections of rail to form frogs and single and double track crossings. The advantages of boltless, jointless, Themit welded tracks are particularly noticable in the case of special work because Thermit welded frogs can be constructed at only a fraction of the cost of manganese or other special work. Furthermore, service tests of over seven years, under heavy traffic conditions, in Milwaukee, Indianapolis, Youngstown and other cities have conclusively shown that Thermit special work has held its own in comparison with other installations costing two or three times as much; in fact it has outlasted manganese insert frogs installed in the same place and subjected to the same service.

Thermit welded special work can be made in the railway shops and the completed layout then transported to the street and quickly set into position and welded to the adjoining rails with minimum delay to traffic. In the case of double track crossings, two halves of the crossing can be constructed in the shops and the projecting arms of each half later welded together in the street. A Thermit welded crossing welded into place will give years of satisfactory service and as compared with any other installation, will save many times its cost.

It is obvious that with a fully welded installation of the kind mentioned above, no conductor cables are required, as all joints will have the full electrical conductivity of the rail itself. This is another advantage which should not be ignored.

Thermit Welded Compromise Joints

Another shop use for Thermit Welding is in connection with making up compromise joints.

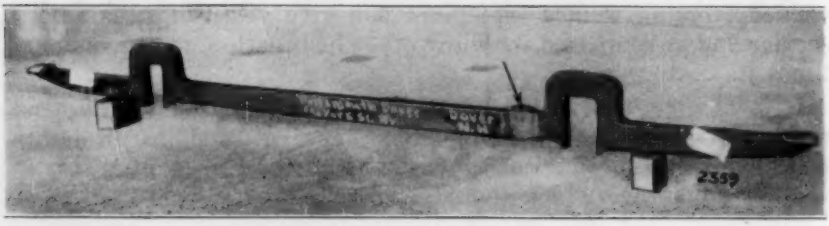
Probably no problem connected with street railway work causes more annoyance and expense to the "way department", in pro-

*Discussion of "Welding for the Maintenance of 1600 Street Railway Cars" by J. S. McWhirter.
†Chief Engineer, Metal and Thermit Corporation.

portion to its magnitude, than the proper maintenance of compromise joints. While at first thought, it might appear that the

Compromise joint constructed by Thermit Welding.

number of these joints on the average street railway system is so small as to be practically negligible, it is a fact that actually there are a great many more than would be reasonably expected. The reason for this is not difficult to find. Owing to the very rapid development of electric traction, with the consequent increase in the weight of rolling stock and speed of operation, it was necessary to increase the size and depth of the rail accordingly. Requirements of modern pavement also demand frequent changes in the design of the rails, so as to offer as little interference with vehicular traffic as possible and still provide a good track. The result is that there is hardly a street railway system in the country that has not a great variety of sizes and types of rail in its track and wherever these various sections come together a compromise joint is necessary.



Thermit repair of broken forged-steel side frame.

When it is considered that for every change of section, two compromise joints on single track and four on double track are necessary, it will be readily understood that, on the older street railway systems particularly, there must be a great many of these joints.

Mechanical joints have not proved satisfactory, as the plates are

seldom accurate and it is exceedingly difficult to obtain either a forged or cast plate which will hold the rails to gauge or surface. Another serious objection is the difficulty of obtaining a satisfactory bond. The Thermit Insert Process, however, will overcome the objections to every other type of joint, with the added advantage that the welds can be made by the street railways themselves either in their shops or in the street and can therefore be had at a minute's notice and without the necessity of carrying a stock of special plates or special cast joints designed for this purpose.

Groups of Thermit-Welded motor cases.

Motor Cases and Truck Frames

Third and fourth important uses of Thermit welding are in connection with welding motor cases and truck frames broken because of stresses from shock and vibration caused by excessive wear of various equipment parts. Crystallization is also caused by vibration and additional strains then cause breakage. Most breakages occur through the actual bearing bore at the gear end of the motor where one end of the gear case is supported. In many cases, these broken motor cases and truck frames can be repaired by Thermit welding at a great saving as compared with the cost of a new section.

OXY-ACETYLENE WELDING IN ELECTRIC RAILWAY SHOPS.

We have all read with a great deal of interest, I am sure, the frequent published accounts of the wonderful progress that has been made by electric and thermit welders in the electric railway field. Some years ago, we were equally impressed with the various trade journal accounts of oxy-acetylene welding and cutting in the construction, operation and maintenance of the street railway, concerning which we now read comparatively little in the public prints.

Doubtless, therefore, it will be a surprise even to some of the rapid transit men in this audience to learn that there is actually more gas welding and cutting in electric railway shops in the country to-day than ever before in the history of the process. This is not true of some individual shops, perhaps, but that it is true of the country as a whole is proved by the steady growth that has obtained in the volume of sales of oxygen and acetylene to electric railway companies. The fact is that all three of the processes—oxy-acetylene, electric and thermit—have steadily increased in both utility and application in the electric railway field.

I think that it is now generally agreed by welding engineers who nave made an impartial study of all welding processes, that each logically occupies a rather definite field. Thermit welding, for instance, is generally conceded to be superior for the joining of very heavy steel sections where the conditions are favorable for its use. Electric welding, especially in an industry where electric current is generated in the regular course of a company's operations, as in the electric railway field, possesses certain advantages of economy over other processes in places where it will stand up under adequate service tests. On the other hand, gas welding and cutting are almost indispensable for a very considerable list of operations, particularly for cast iron welding and for reclamation work where welded joints are subjected to unusual strains and vibration and of course, to all wrecking and demolition work.

While electric and thermit welding have been gaining ground, and even displacing oxy-acetylene welding in some directions, gas welding has more than held its strong position in the electric railway industry by virtue of the remarkable development of reclamation operations, which has resulted from the extension of modern efficiency methods. Very likely some of you may be inclined to take issue with me on this point, because there are instances where master mechanics personally favor a single process for all welding operations, irrespectively of its greater or lesser fitness in any par-

---

Paper to be read by T. Gillespie, Sales Engineer of the Oxweld Acetylene Company, before the Joint Meeting of the American Welding Society and the American Electric Railway Engineering Association, at Chicago, October 4, 1922.

ticular case. It is only natural in such instances that he should incline to the electric process, because of his familiarity with electricity, the availability of the current and the apparent economy of the arc.

I feel quite sure that any unbiased inquiry into welding in the electric railway field will yield convincing evidence that the companies which are obtaining maximum ultimate economics are those which are intelligently applying each of the three processes where it is called for by the best established practice. There will always be a no-man's land between a distinctly oxy-acetylene and a distinctly electric application and it may possibly be a broader zone than the rather finely drawn line dividing oxy-acetylene and thermit welding applications. The overlapping of the thermit and electric processes, on the other hand, again tends to widen. All these afford battlegrounds for controversy and tend to distract attention from the broader facts that lie unchallenged by experience and engineering knowledge. To me the situation appears clear as to the importance and practical necessity for all of the welding processes that are at present available in electric railway work.

It may be of interest to some of you who, perchance, do not at present use oxy-acetylene welding to a very considerable extent, for me to enumerate a suggestive list of operations that are of daily occurrence in the gas welding departments of some of the country's large electric shops. I shall not attempt to make the list complete but it will suffice as an illustration.

For example, one street railway company in a large city of the Central West has conducted a Central Welding Shop for the past eleven years, employing the oxy-acetylene process on such application as

Building up Journals on Car axles;
Reclaiming Truck Sides-Repairing when broken and Building up when Worn;
Repair and Reclamation of Transom Bars;
Reclaiming Cast Steel Motor Shells—Repairing when broken and Building Up when Worn;
Building up Bolster Ends;
Repairing Broken Cast-Iron Motor Shells;
Building Up Armature Shafts;
Building Up Worn Equalizers and Radial Bars at Ends;
Building Up Worn Flanges on Wheels;
Construction and Repair of Gear Shields;
Repairing Truck Ends;
Restoring Worn Ends;
Reclaiming Worn Brake Shoes;
Repair and Building Up of Axle Caps, Air Compressor, Gear Case and other lesser Parts of Car Frames.

Another very large electric railway company, one of those in an

Eastern metropolitan center, employs the oxy-acetylene process in welding of

Pedestal Liners; Expansion Jaw Bolts; Journal Boxes; Tube Insertions; C. I. Gear Teeth and Breaks; Brake Cylinders; Power Station Cylinders; Equalizer Bars and Parts; Door Bars; Fly Carriers; Expansion Bars; Rail Draw Bars; Wheel Press Bases, (Repairs); Tool Steel Tips to mild Steel Shanks (in Machine Shop); all Bars and Bearings; Filling in Pin-Holes, Sand Holes and Flaws in Castings, etc.

Yet another street railway company in one of the larger New England cities employs oxy-acetylene welding for
Welding Broken Gear Cases; Welding Lugs onto Gear Cases; Welding Lugs onto Hand Hole Covers; Welding Transformer Boxes, Welding Motor Cases, Axle Caps, Air Governors, Chair Posts, Brush Holders, Axle Bearings and Armature Bearings.

It will be noted that there are comparatively few duplications in the applications enumerated as being used by these three companies. Wherever oxy-acetylene is used to any considerable extent one almost always notes some applications that are not commonly employed in other places, though very often the oppertunity is present. A complete list of all of the applications that are being successfully employed in the use of oxy-acetylene by the leading users of the process in the electric railway field would be an imposing one.

Bearing in mind that the companies which are using oxy-acetylene most extensively also have their well-ordered electric welding departments and the fact that both gas welding and electric welding are growing in volume—and the same is also true of thermit welding, if I am correctly informed—I say, bearing these things in mind, one begins to realize the immense field that has been developed for welding by all of these processes of recent years in the electric railway industry.

I suppose some of you may have expected a particular reference to the welding of rail bonds. A great deal has been written on the subject. All manner of tests have been run with a view to establishing the superiority of one process or another, as well as tests of various types of bonds without special reference to the welding process employed. I wish merely to state, for the information of those present, that welding of bonds by the oxy-acetylene process is extensively employed today by large electric railway companies in every section of the country. The U. S. Bureau of Standards gives the oxy-acetylene bond a very high rating, as you all probably know and though its cost is somewhat higher than that of the electric welded bond, especially where current is charged against operations instead of being debited to upkeep, there are still master mechanics and construction engineers who believe that there are

physical compensations which more than offset this difference.

Gentlemen, I whole-heartedly congratulate the Welding Fraternity, without reference to any particular process they may favor or represent, on the splendid progress each and all are making. Though the interests of individual processes at times come into conflict, their service to American industry is a common one and any real good the welding industry partakes of is, after all, only the fruit of benefit sown in the way of practical help to the users of welding processes. This view, I believe, is coming to be shared by the Welding Industry as a whole and I cannot but feel that it is this attitude, more than anything else, which is nourishing the confidence of American Industry for Welding today.

EMBLEM

All members of the Society are privileged to wear the Society emblem. Emblems may be obtained in two styles from the Secretary's office. Price, gold-filled, 75c., 14-K. gold, $5.00.

WELDING OF CAST IRON

EXPLANATORY NOTE BY THE SECRETARY OF THE AMERICAN BUREAU OF WELDING

(The American Bureau of Welding is the Joint Advisory Committee of the American Welding Society and the Division of Engineering, National Research Council, on Welding Research and Standardization).

The nature and properties of cast iron affect its weldability and a clear understanding of these properties is consequently necessary for the successful execution of welds made by the electric arc, gas or thermit methods. The subject has accordingly been divided into four parts. The first covers the general properties of cast iron and the various elements which affect its weldability and the other three protions deal with specific applications of electric, gas and thermit methods.

First Part — General Consideration

The first part, dealing with the general properties of cast iron and the various elements which affect its weldability, has been prepared through the joint efforts of the Electric Arc, Gas and Thermit Welding Research Committees of the Bureau. It is therefore a report of the American Bureau of Welding and has been released for publication by that body.

Second Part — Electric Arc Welding of Cast Iron

The Electric Arc Welding Committee of the American Bureau of Welding, under the chairmanship of Mr. H. M. Hobart, recognizing the need for a thorough investigation of the electric arc welding of cast iron, assigned this problem to the Northern New York section of the American Welding Society. Mr. William Namack accepted the chairmanship and gathered together on his committee, several members of this section. This regional concentration of members permitted the holding of regular meetings at frequent intervals, of sustaining interest and enabled progress to be made at a much greater speed than could otherwise have been possible.

The efforts of the Committee were directed into two channels, namely, the preparation of a critical summary of the present state of the art and the investigations of those phases on which data was lacking.

The paper given in this issue serves as a critical summary of the present state of the art and aims to set forth recognized procedure in each of the special methods now successfully used in the welding of cast iron. This report has been presented to the American Bureau of Welding for adoption by that body. The Bureau invites discussion and suggestions from all of those who have had experience in this field. Kindly send all communications to Secretary W. Spraragen, 33 West 39th Street, New York City.

As stated above, the Committee of the Northern New York Section, has also undertaken a program of research on those problems needing investigation and where authentic information is lacking. The results of these tests and investigations will be published in the next issue of the Journal.

Third Part — Gas Welding

A summary of the present state of the art of gas welding was prepared through the courtesy of Mr. S. W. Miller, Chairman of the Gas Welding Research Committee of the American Bureau of Welding. The Bureau would like to have the benefit of the experience of additional members of the American Welding Society in enlarging this portion and solicits your aid.

Fourth Part — Thermit Welding

A summary of the thermit welding of cast iron will be published in the next issue of the Journal.

CAST IRON WELDING

GENERAL CONSIDERATION

A Joint Report of the Electric Arc, Gas and Thermit Welding Research Committee of the American Bureau of Welding.

For years it has been common practice to repair defective iron castings in the foundry, by cutting out the defect, forming a sand mold around it and then pouring very hot melted iron into the mold and allowing it to overflow and waste, until the surface of the defect is melted, when the mold is allowed to fill, the supply of melted iron is cut off and the casting allowed to cool. The process is called "burning in." In many cases good results are obtained, but frequently, there are disadvantages of high cost, cracked castings and the difficulty of machining the "burn" or the metal near it.

Modern methods of repairing cast iron parts are replacing the old practice, with better results in every way. There are still, however, many matters that need more study.

Field for Cast Iron Welding

The field for possible applications of cast iron welding is enormous. At present, unlike the welding of steel, the welding of cast iron is confined entirely to repair or salvage work. However, with the further perfection of methods of making strong, homogenous, machineable welds in cast iron, at a reasonable cost, there is reason to believe that the art of welding may be employed in the fabrication of structures of cast iron, just as it is at this time used in joining cast steel sections.

But, in repair work alone, cast iron welding can be extensively used and effect great savings. Consider the foundry in which the castings are manufactured; welding can be and is employed to fill up blowholes and gas holes; to build up castings that do not quite meet the required dimensions; and for various other purposes, making useful castings of what would otherwise be scrapped material, saving expense for the foundryman and delay for the purchaser of the castings.

After the castings leave the foundry and go to the machine shop, further defects, remediable by welding, may be uncovered by the machining process. Or the machinist may inadvertently remove too much metal, which can be replaced by welding. Here are other opportunities for welding to make further savings of time and money, before the casting even reaches its final destination.

Then, when the iron casting has become a part of an engine, a generator, a boring mill, a punch press, an automobile, a sewing machine, or what not, there is always the chance that some unusual strain to which the machine is subjected, a flaw in the casting, or some other cause, will cause its failure, resulting in loss of use of the machine of which it is a part until it can be replaced

or repaired. In the case of large important castings, the time required for obtaining a new one may be a matter of weeks or months and the expense involved very great, especially if the loss of output from the disabled machine is considered.

Here is the great field for cast iron welding—namely—the repair of broken castings. In some cases the possibility of doing the repair without removing the broken part from its operating position alone effects a large saving in time and money. In others it is the expense involved in scrapping the broken casting and obtaining a replacement which is the important item. In still others, time is the all important consideration. In all these cases, if a satisfactory method of welding is available, and economic saving will be effected and any process that can bring about savings of time and money to industry in general, deserves earnest and thorough study and investigation in an effort to advance or perfect its use.

Iron Ore—Pig Iron—Cast Iron

Cast iron, as presented to the welder, is obtained from pig iron, which has been produced by smelting iron ore in the blast furnace. The molten iron, while in the blast furnace, comes in contact with other elements existing in the ore or fuel and takes them up to an extent depending on the amount present and the conditions under which the furnace is operated.

Some of these elements, notably carbon, silicon, sulphur, phosphorus and manganese, are obsorbed by the iron in large amounts and as these amounts vary, so do also the physical properties of the cast iron. It is quite probable that they also effect its weldability to some extent, tho this needs further research. Carbon is by far the most important element and has the greatest effect, while the others are all of value at times, except sulphur, which is always injurious even in small amounts.

The molten iron from the blast furnace, with its content of carbon, silicon, manganese, sulphur and phosphorus, is cast into pigs, which are shipped to the foundrymen to be made into iron castings.

Control of Composition and Characteristics of Iron Castings

The foundryman places the pig iron, with possibly some scrap iron or steel and the necessary amount of fuel, usually coke, in a cupola and melts it. When it is in the melted state it can again change its characteristics by absorbing elements with which it comes in contact.

Thus, the foundryman can to a certain extent, control the composition of the iron which he taps from the cupola by mixing pig irons and scrap which contain different proporations of these various elements and by using fuels which contain small amounts of injurious elements, such as sulphur. Fluxes are sometimes used with good effect and various elements, such as silicon or manganese, may be added by introducing ferro-alloys containing high percentages of these materials, into the charge.

The physical properties of the iron casting may also be varied by the method of casting. Thus if a mold is so made as to quickly chill the molten iron, a large proportion of the carbon will remain in the combined state, making a very hard casting. This effect will be explained more in detail later in the report.

Influence of Impurities on the Properties of Cast Iron

Carbon appears in cast iron in two forms, namely, combined and in the free state as graphite, sometimes called graphite carbon. When in the combined state, it is in the form of iron carbide, (Fe, C), frequently called cementite, a chemical compound of iron and carbon. It is very hard and brittle and has little strength. When free graphite is present, it retains its own characteristics of softness and weakness.

All cast iron contains carbon, usually from 3 to 4 per cent, but the amount of this held in the combined form depends on the rate at which the casting is cooled and also on the amount of other elements, principally silicon, present in the iron. When the iron is molten, practically all the carbon is held as iron carbide. Now if the casting is allowed to cool very slowly, nearly all of the carbon will pass out of the combined state and segregate as free flakes of graphite. On the other hand, if the iron is cooled with extreme rapidity, a large proportion of the carbon will remain in the form of iron carbide.

When the carbon is in the free or graphitic state, it is mixed with the iron in the form of flakes and as neither pure iron nor graphite is hard or brittle, the result is a relatively soft metal, one which can readily be machined. However, the flakes of graphite separate the grains of iron from one another, thereby weakening the metal.

If the carbon is practically all in the combined state, the metal is very hard and brittle and difficult to machine.

Cast irons, containing a considerable amount of graphitic carbon, are known as gray cast irons because of the appearance of their fracture, which is gayish or blackish and coarsly crystalline. Those containing only combined carbon and free, therefore, from graphite carbon, are called white cast irons, from the aspect of their fracture, which is white, brilliant and highly metallic.

Silicon reduces the solubility of carbon in molten iron, so that pig irons of high silicon content have a low total carbon content. The most important effect of silicon from the standpoint of welding, is that it increases the proportion of free to combined carbon, thereby making the metal soft and machinable, as explained above. Thus, while the presence of silicon may not directly affect the weldability of cast iron, it is of great importance since its introduction in the weld has a strong softening influence. Silicon also helps to eliminate oxides, promote fluidity and decreases shrinkage and chilling effects.

Sulphur exerts a very bad effect on cast iron and should be kept

at a minimum. It tends to cause the carbon to be held in the combined state. This increases the hardness and also the shrinkage since carbon in the combined form occupies less bulk than graphite. It also renders the iron very weak, while at a red heat, unless a sufficient amount of manganese is present. Sulphur also makes the iron solidify more rapidly in cooling down from a red heat, thereby often causing blowholes and shrinkage holes or cracks.

Thus sulphur tends to maks the iron white, hard and brittle. Its effects can be partially counteracted by silicon or manganese additions. Silicon will precipitate the carbon as free graphite, even if sulphur is present, while manganese will combine with the sulphur to form manganese sulphide.

Phosphorus, lowers the melting point of cast iron and makes it hard, brittle and weak. In the amounts ordinarily present in foundry irons, it has no effect on the ratio of combined to free carbon, but itself forms a compound with iron and iron carbide, which is hard and brittle, has a low melting point and confers these properties on cast iron. If enough silicon is present to prevent the formation of iron carbide, the iron will be softer, but still brittle.

The amount of phosphorus is usually kept as low as possible, except in castings having very thin sections, where a very fluid iron is necessary to ensure filling all parts of the mold. In such cases, a high phosphorus iron is used because of its fluidity, in spite of its weakness and brittleness.

Manganese has several effects on cast iron. Its principal one is to combine with the sulphur, forming manganese sulphide, which occurs in small gray particles, which, unless segregated, have little effect on the strength of the casting. It also helps to deoxidize the metal. Further, is combines with some of the carbon, making (Mn, C), manganese carbide. This has the same properties of hardness and brittleness as iron carbide, so that while by combining with sulphur, it softens the iron, it hardens it by combining with the carbon. As neither the sulphur nor manganese is uniformly distributed in the metal, it is necessary to have an excess of manganese present, to be sure that all of the sulphur is taken care of.

General—.From the foregoing brief statements, it is evident that the effect of any one element on the properties of cast iron is dependent on the amount of the various other impurities present and upon the rate of cooling of the casting. The effects are in many cases much more complicated than have been indicated. A full discussion of this subject is far beyond the scope of this report.

Classes of Gray Iron Castings—.Since gray iron castings are machineable and in other ways better than white iron for most purposes, the majority of castings presented to the welder will be of gray iron. For practical purposes, gray iron castings can be divided into three classes:

(1) Machinery Castings; (2) Stove Plate; (3) Specialties, such as Structural Castings.

Machinery castings, as the name implies, are castings which are made as strong as is compatible with having them soft enough to be machineable. It is evident that this class includes irons of wide-

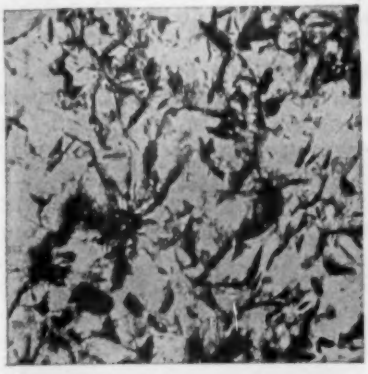


Fig. 1
Gray Cast Iron etched with HNO_3 magnified 75 dia.

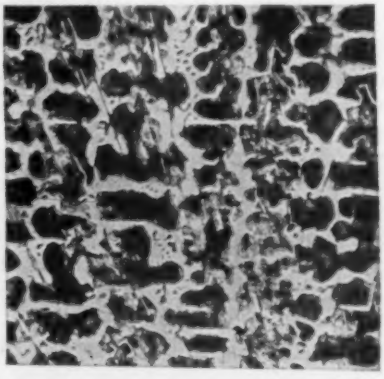


Fig. 2
White Cast Iron etched with HNO_3 magnified 75 dia.

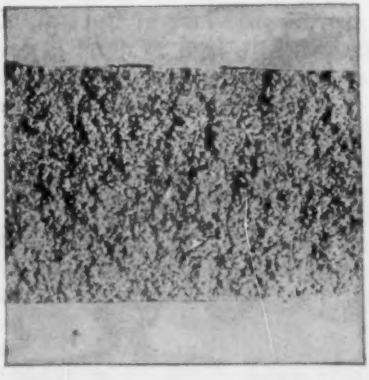


Fig. 3
Gray Cast Iron Fracture.

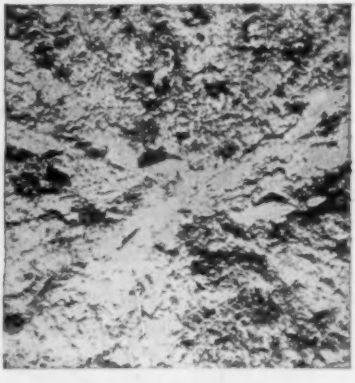


Fig. 4
White Cast Iron Fracture.

TYPICAL ANALYSIS OF "GRAY" AND "WHITE" CAST IRON

	Gray	White
Total Carbon	3.30%	3.20%
Graphitic Carbon	2.80%	(all combined)
Combined Carbon	0.40%	3.20%
Silicon	2.50%	0.80%
Manganese	0.50%	0.45%
Phosphorous	0.60%	0.20%
Sulphur	0.10%	0.15%

ly varying composition, as the foundryman will vary the mixtures according to the size and shape of the castings which he is making as well as the use to which it is to be put. Castings of very heavy cross-section will be machineable even though they have a low silicon content. This is true because the heavy section ensures a slow rate of cooling and much silicon is not needed to cause the precipitation of free graphite.

Stove Plate castings are necessarily of thin cross-section and consequently are usually made from iron containing high percentages of silicon and phosphorus. When castings, even though they be of heavy section, such as grate bars, are made in a stove plate foundry, they usually are of this same grade of iron.

Structural Castings are made for strength alone. Of course there are exceptions to this statement, such as certain columns and special shapes, which require machining. A casting from a specialty shop, or a structural casting, will use a high percentage of combined carbon.

In figures 1, 2, 3 and 4, are illustrated the two extremes, a gray iron, in which practically all of the carbon is in the free state and a white iron, in which almost all of the carbon is in the combined form. The greater the proportion of free or graphitic carbon, the darker will be the appearance of the fracture and the grain will be coarser and more open, showing large crystals of iron with intervening flakes of graphite. Filings from such an iron will soil the hands or mark on paper, owing to the presence of the graphite On the other hand, the fracture of the white iron is light in color and brilliant and is close grained, with small crystals. Thus, from the appearance of the fracture, it is possible to estimate the proportion of free to combined carbon and thus determine in a measure, the characteristics of the iron to be welded.

Factors Affecting Cast Iron Welds

Carbon—.In making a weld in commercial cast iron, the surfaces which are to be joined must again be melted. These surfaces consist of iron which contains carbon in both the free and combined states. When these surfaces are melted, several things happen. First, both the graphitic and combined carbon go into solution in the molten metal. Second, some of the carbon, silicon and manganese are burned out by the heat, while the amounts of sulphur and phosphorus are practically unchanged. Silicon is most easily burned out, so the tendency is to produce a cast iron, in the weld, that will be white when cold, owing to its low silicon and carbon content. Third, the surface of the molten metal oxidizes, making a slag, which in a measure prevents further oxidation.

As soon as the welding heat is removed, the melted iron solidifies very quickly, owing to its proximity to the comparatively cold mass from which it has been melted and to its being exposed freely to the air. This sudden cooling causes a large amount of the carbon to be retained in the combined state, resulting in a white, hard, metal in the weld. Of course if the casting has been

preheated before welding, the cooling of the added metal will not be so sudden and a softer machineable weld may be secured.

Experience has shown that the grade of cast iron which is most difficult to weld successfully, is that which is soft and has an open grain. However, little difficulty is encountered when the metal is of comparatively thin (one-half inch or less) section.

Oxidation—.When iron is molten, or even red-hot, it oxidizes very readily if exposed to the air. Thus in welding, the surface

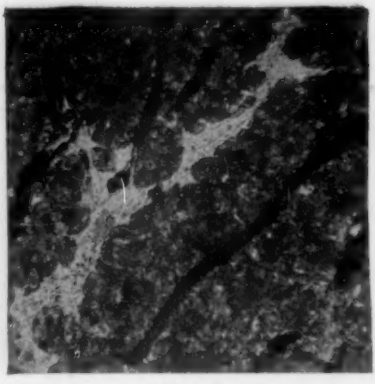


Fig. 5

Hard Close-grained Cast Iron. Matrix all pearlite. Graphite plates moderate in size. White spots phosphide eutectic. From hydraulic cylinder (100 X).

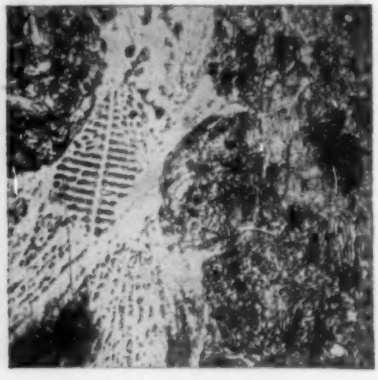


Fig. 6

Same as No. 5, but 430 X.

Fig. 7

Machine cast iron heated red hot and quenched in ice water. Matrix is martensite with graphite plates showing black. White spots are iron phosphide which the rapid quenching prevented from becoming phosphide eutectic (100 X).

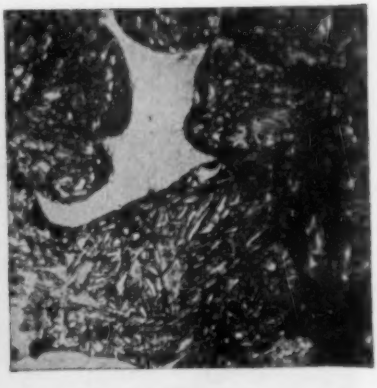


Fig. 8

Same as No. 7, but shows structure more clearly. 430 X

of the molten metal becomes covered with iron oxide, which may be deposited in the weld by mixing with the molten metal, or by

being tapped between two layers of metal added at different times. In either case, the result will be a weak, non-homogeneous weld for the oxide particles segregate and do not form a junction with the adjacent metal.

Shape of Casting.—The shape of castings must also be taken into consideration. A casting comprising both light and heavy parts is subjected to more internal stresses than one of homogeneous cross-sections. These stresses are caused by the different rates of

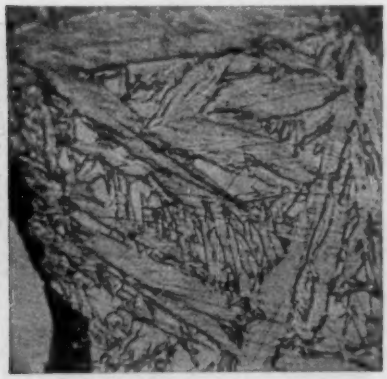


Fig. 9

Same as No. 7, but 1200 X showing clearly the martensite structure of the matrix.

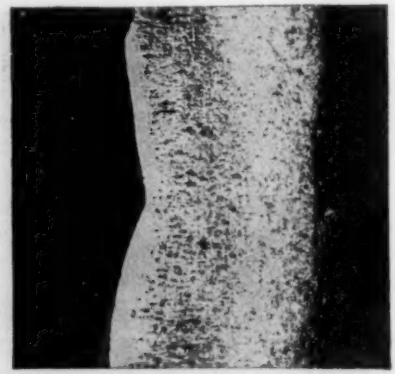


Fig. 10

Hard spot in cast iron made by just melting surface with torch and allowing it to cool in air. The rapid cooling has changed it to chilled iron (2 X).

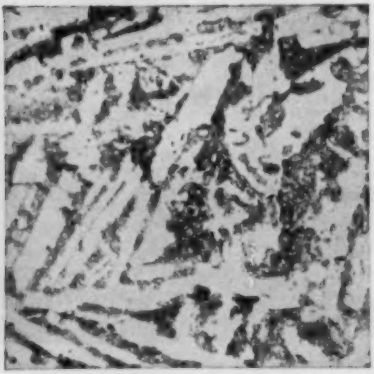


Fig. 11

Structure of chilled iron in hard spot. White is cementite, matrix pearlite with a few spots of graphite (100 X).

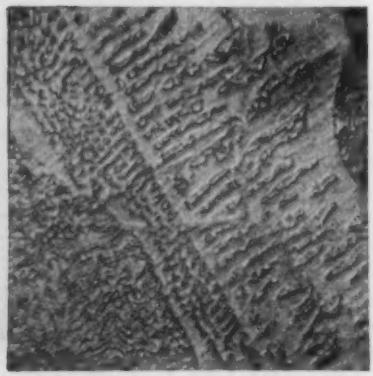


Fig. 12

Phosphide eutectic in cast iron with pearlite fringe around it (1200 X).

cooling, light sections cooling more rapidly than heavy. There are also internal stresses set up at sharp angles. The influence of the

shape of casting on the method of welding is taken up in greater detail the papers dealing with electric, gas and thermit welding of cast iron.

Shrinkage.—When in the welding of cast iron, a filler metal of different composition than that of the casting is used, serious consideration must be given to the fact that the co-efficient of expansion and consequently the shrinkage of the metal in the weld may be different than that of the rest of the casting.

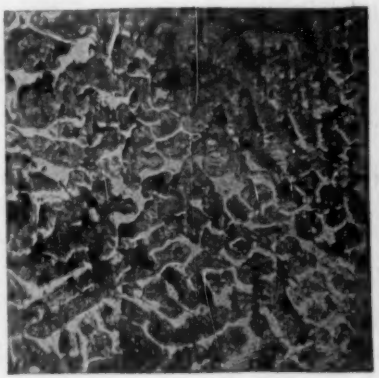


Fig. 13

Chilled iron casting. The White is cementite, the matrix pearlite and there is some carbon as graphite at the right (100 X).

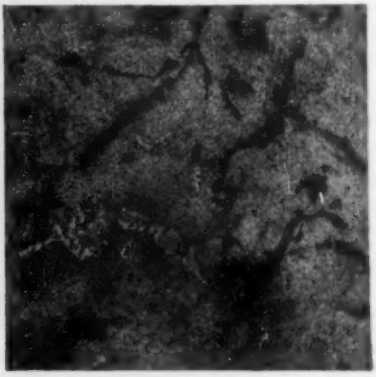


Fig. 14

Another close-grained cast iron with less graphite than No. 5 and also less phosphorous (100 X).

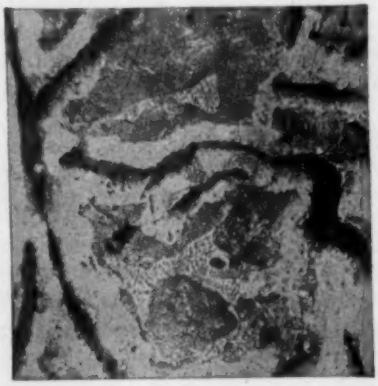


Fig. 15

Good machine iron. Ferrite around graphite plates and rest of the matrix pearlite. Graphite plates of moderate size and number (200 X).

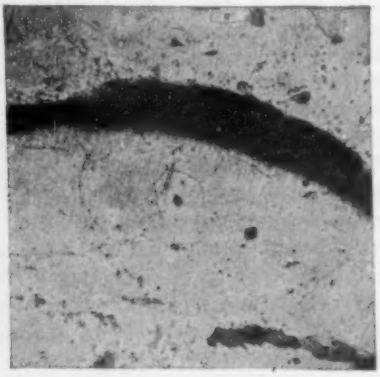


Fig. 16

Very soft cast iron. No. pearlite. Matrix all ferrite. Graphite plates large. Taken from large casting in dry sand (200 X).

The different shrinkages of the two metals will tend to cause one to slide on the other as they pass from the liquid to the solid

state. This shrinkage of course sets up internal strains which the ductility of the welding material must take care of. Altering the carbon content from the combined to the graphitic state helps decrease the shrinkage. If the iron contains a weakening agent the internal strains set up by shrinkage often causes cracks to appear.

Summary.—From the foregoing, it is evident that the term Cast Iron is applied to metal of widely varying composition and characteristics. Cast iron always contains in the neighborhood of 3 per

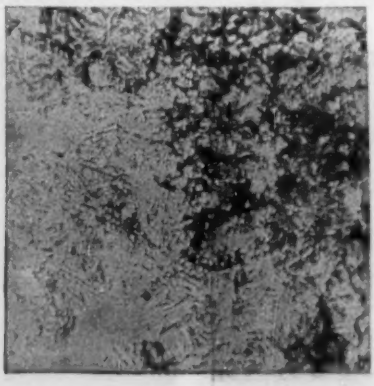


Fig. 17

Cast iron gas welding rod heated bright red and quenched in ice water. The structure is martensite, but there is enough silicon present to keep some carbon in the form of graphite (430 X).

cent of carbon, but this may be in either the combined or graphitic state and it may hold widely varying amounts of other elements, as silicon, manganese, sulphur and phosphorus. Not only the presence of these elements, but also the rate of cooling of the casting, profoundly affect the physical characteristics and weldability of the metal.

In papers which are to follow this, the Electric Arc, Gas and Thermit methods of welding cast iron, the results obtained by them and the subjects requiring further study and research, will be covered in detail.

ARC WELDING OF CAST IRON *

By W. H. NAMACK †

This paper constitutes a report of the Sub-Committee on the Arc Welding of Cast Iron, of the Northern New York Section of the American Welding Society. It presents a summary of the art as it exists today, outlining the difficulties that have been encountered and the degree of success which has been achieved. In the paper is described the research work which the Committee has carried out and suggestions are offered for further research. Descriptions are given of typical cast iron arc welding operations by various methods.

There are two fundamental methods of arc welding cast iron, namely, (1) by the carbon arc and (2), by the metal arc. The latter may be divided into (a) metal arc welding with studs and (b), metal arc welding without studs. Each type of welding mentioned will be treated in the order named.

Carbon Arc Welding of Cast Iron

Carbon arc welding is used over a considerable range of application and somewhat resembles the oxyacetylene method, one difference being the way in which the heat is produced. Difficulties are encountered in welding thin sections by the Carbon Arc Process. In welding cast iron with the carbon arc, the casting is sometimes preheated. When this is done, the same precautions must be used (both during heating and cooling), as in the case of gas welding.

Obviously it would be desirable if the weld area could have the same composition and characteristics as the original cast iron. With a view to approaching this result, the conditions under which the weld is made should preferably be similar to those employed in making cast iron and the same precautions taken with respect to slow uniform cooling to allow for precipitation of the carbon from the combined state, in which it exists in the molten cast iron, into the graphitic state in the finished weld. The welded part will be machineable to the extent to which this result is attained. Welds of this kind are possible with the carbon arc method, if the precautions suggested in the following paragraphs are followed.

Preheating

Unless the work is very small and of simple form, it should be preheated to a "dull red" heat to minimize shrinkage stresses. Where the work is complicated, slow heating is necessary. Uneven heating may cause warpage and introduction of stresses.

---

*To be presented at Fall meeting, American Welding Society, Chicago, Oct. 3, 1922.

†Chairman, Sub-Committee on Electric Arc Welding of Cast Iron, Northern New York Section, A. W. S.

Manipulation.

The arc is applied to the edges to be welded until the iron commences to melt. Then the bottom of the V is melted down, applying during the fusion, a little flux or scaling powder with the heated end of the filler rod. It is important that the two edges to be joined should melt at the same time. Metal from the filler rod should not be added until the bottom of the V has been filled by metal from the sides. When ready to add metal, the end of the filler rod should be placed in the melted metal of the weld and the arc played on both the rod and the weld so that the metal runs together. The rod should be dipped in the scaling powder as often as is necessary and the filling in process continued. However, too much scaling powder should not be added at one time. Only just enough is needed to make the metal run freely. The weld shrould be made in steps. If too much metal is added in one place, it is likely to run into the bottom of the V and unless the welder is experienced and careful, this will cause a "cold shut" and the weld will be defective. As the filling progresses, the operator should satisfy himself that the metal is welded at both sides.

The melting of the filler rod should take place as much as possible in the molten bath in the bevel by plunging in the rod and then playing the arc all around. This method should always be used for great thickness.

Certain essential manipulations are sometimes difficult to execute. For example, the fluidity of the metal when melted does not permit of making vertical welds. It is therefore desirable to arrange the line of welding as nearly horizontal as practicable, although this is difficult with certain shapes and sizes of pieces to be welded.

The fluidity of molten cast iron makes it necessary in certain work, to suitably surround or support the edges to be welded in order to prevent the metal from flowing away.

Filler Rod and Flux

One advantage of the carbon arc process is that the filler rod can be of cast iron, thus permitting of actually depositing cast iron in the weld. This procedure will, when a suitable flux is used, tend to produce the same general characteristics as those of the base iron. To the extent to which this is effected, the subsequent machining of the parts will be practicable.

A good flux can be made of a mixture of equal parts of carbonate of soda and bicarbonate of soda. Washing soda is the name commonly given to a somewhat impure carbonate of soda, while bicarbonate of soda is ordinary baking soda. There is no necessity that either should be in a chemically pure state. The action of the carbonates is to combine with the oxygen in the slag, releasing the iron and allowing the oxygen to pass off in the form of carbon monoxide or carbon dioxide.

With cast iron, the oxide formed is lighter than the melted metal and does not flow at quite so low a temperature. The slag which forms on the surface of the iron therefore tends to hold the melted metal into place. Scaling powder should be added by dipping the rod into the powder, only when the metal does not flow well and no more should be used than is necessary.

When using a flux in welding cast iron, it will be noticed that as soon as a small portion of it is put on the melted iron, the surface of the metal becomes clear and mirror-like, thus making a a good weld possible.

Electrode Material and Current for CarbonWelding

Mr. O. H. Eschholz of the Westinghouse Electric and Manufacturing Company gives his opinion in regard to the relative advantage of graphite electrodes over carbon electrodes as follows:

"I would suggest that distinction be drawn between the use of graphite and carbon. Graphite is unquestionably the superior, both in case of maintaining arc, life of electrodes and reduction in carbon transference. Cast iron filler rods of ¼", ⅜" and ½" with corresponding currents of 250, 325 and 400 amperes are frequently enployed."

Annealing.

After the weld has been completed, it is desirable that the cooling should be as slow as possible. For articles which have been preheated it is best to replace them in the oven and cover them completely with asbestos or some other non-conductor, so as to avoid local cooling.

Many articles of cast iron, although they have been properly welded, break or crack in cooling, either in the line of welding or elsewhere, owing to a failure to observe such precautions as shall prevent local contraction.

When a coke or charcoal fire has been used for preheating, the piece welded should be completely covered with cinders or charcoal; refactory bricks or sheets of asbestos should be placed on the sides and underneath, so as to avoid all draughts of cold air and the article should be left until it is completely cold. Sometimes it is necessary to allow twenty-four hours for cooling.

Mr. J. H. Proper, Welding Foreman of the General Electric Company, at their Schenectady plant, speaking of his experience with carbon arc welding, is quoted as follows:

"The carbon arc process is used for building up undersized stock and blowholes in castings and quite extensively in repair work being in many instances cheaper and quicker than either the acetylene or the metallic arc processes. In the work here, the following sizes of electrodes, current values and sizes of filler rod have been found most successful:

Dia. of Carbon Electrode	Amperes	Filler Rod
½"	150-300	¼"
¾"	300-500	⅜"
1"	400-800	½"-⅝"

The use of the above electrodes and current values depends upon the size of the casting and the speed with which the welding must be done. In many instances, scrap iron can be used for filler rod. An example of such a job is the "wearing back" of an ash shute. No filler rods over ⅝" in diameter are used here.

We do not use flux in carbon arc work and any clean cast iron rod is suitable for filler material.

Sometimes current values as high as 800 amperes have been used, but when using this high current, the operator rests at intervals, because of the great heat. When welding on a preheated casting allowances are made for the heat by the operator removing surplus clothing.

"No two operators are alike in the choice of glass combinations for welding shields, but the usual combination is red and green with varying numbers of plates of each.

It is always our policy to preheat castings to prevent cracking by expansion and contraction, but I do not consider it *necessary* to preheat to get a good weld. In preheating castings, either a suitable preheating furnace or portable torches may be used, depending on the size and shape of the casting. Experience is necessary in handling the preheating operation.

Castings vary somewhat in internal stress conditions with different moulders and for this reason many welds fail because the welder cannot know the internal make up of the casting on which he is working. These failures are blamed on the electrode and the welding process, neither of which may be faulty.

The carbon arc process gives better results on heavy work than the metallic arc. An arc length of from about ⅜" to ½" depending on the size and shape of the casting, is used with all currents depending on the rate of heating desired

In depositing metal the filler rod should be held in the rear of the arc, for if the rod is held in front of the arc the fluid metal is liable to run over on the cold metal and cause what is called a "cold shut".

Problems and Methods of Metallic Arc Welding of Cast Iron

Much cast iron arc welding is now done with the metallic arc process. In this process an arc is drawn between a metal wire electrode and the base metal, the filler metal being supplied by the melting of the electrode. In this respect, the process is exactly the same as that employed in the metallic arc welding of steel. However, owing to several circumstances amongst which may be mentioned the high percentage of impurities contained in cast

iron, its brittleness and low strength and its comparatively low melting point, the making of a dependable cast iron weld is very much more difficult with cast iron than with mild steel.

Penetration.

It is extremely difficult to obtain good fusion of the filler metal with the cast iron, or as it is commonly termed, good "penetration." This is particularly true of gray iron, white iron being distinctly easier to weld. The greater difficulty of welding gray cast iron seems to be due partially to the flakes of free graphite present. These tend to separate the filler metal from the cast iron and also tend to separate the grains of iron from each other.

Carbon Content

In welding cast iron by the metallic arc process, the suraces to be joined are melted by the heat of the arc between the electrode and the base material. In gray iron, these surfaces consist of iron which contains carbon in both the combined and uncombined states. As soon as the heat of the arc is removed, the melted iron solidifies very quickly, owing to its proximity to the comparatively cold mass from which it has been melted by the arc and further owing to its being exposed to currents of cold air. Naturally this portion of the metal which has been made liquid and has cooled quickly, is very hard and furthermore any uncombined carbon which is brought to the surface, also has a deteriorating effort on the weld, since it acts as a separator between the deposited metal, (assuming that the filler metal is deposited in layers) and the metal which was melted on the surface of the cast iron.

Oxidation.

When iron is brought to a high temperature in the presence of oxygen, as in welding, oxidation of the metal takes place. When it becomes oxidized the oxide segregates out and being in a granulated state it will, if trapped in the weld, cause a weakness and make it impossible to fuse the added metal to it. This difficulty may be overcome, if due care is exercised in removing this surface oxide by means of a stiff wire brush.

Shrinkage

As the metal in a weld cools from the molten state, its volume decreases considerably. For example, the contraction of cast iron in cooling from its melting point to ordinary room temperature is approximately one per cent. This amounts to one-eighth of an inch per foot of length. Consequently, if the two parts being welded together are not free to move in response to the forces set up by the contraction of the weld metal, very severe stresess will result. As cast iron has practically no ductility, these stresses may break the casting, unless they can be relieved by the stretching of the filler metal.

The situation is complicated by the fact that if steel is used as

a filler metal, as is ordinarily the case, (i. e. if a steel electrode is employed), the shrinkage of the filler metal is from 50% to 100% greater than that of the cast iron itself, since the contraction of steel, during cooling, is from 1.5% to 2%. Therefore, there is a tendency for the filler metal to slide over the iron, often resulting in a break at the line between the filler and base metals.

Shape of Casting

The shape of the casting must also be considered in connection with shrinkage. If a heavy section is heated up by welding and if its expansion, when heated, throws a stress on a lighter section elsewhere in the casting, that lighter portion is liable to fail. Again if a light and heavy section are heated equally and then cooled, the lighter section will cool, (and consequently contract), faster than the heavy section and a break through the lighter section is liable to occur.

The Use of Steel Studs

A very successful method of overcoming troubles due to shrinkage consists in employing steel studs screwed into the cast iron, the filler metal being welded to them. These studs pass through the brittle layer of iron at the weld and transfer the stresses to the mass of metal back of the weld.

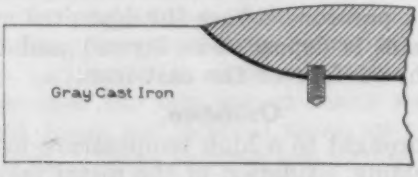


Fig. 1
Illustration of a single stud and its location relative to the hard zone.

Obviously the use of studding entails considerable expenditure of time and labor, owing to the necessity for drilling and tapping the holes and inserting the studs. It appears, however, to be the consensus of opinion of arc welding specialists that studding should at the present stage of our welding experience, be employed when the cast iron parts are not free to adjust themselves in response to the contraction stresses set up during cooling.

In applying the studding method it is general practice to so chip out the crack to be welded as to form a V. Studs are then inserted in one or more rows, either in the faces of the V or alongside it, or at both these locations. Studs on one side of the weld are placed opposite the corresponding studs on the other side. If, however, more than one row of studs is used, the studs in adjacent rows on each side are usually staggered. The stud holes are drilled and tapped with a bottoming tap. The studs are screwed

in tight, completely filling the hole for a depth of about one and one-half to two times the diameter of the stud. It is convenient to use rods threaded for their entire length. These are screwed in tight and are sawed off at a distance of 1/8" or more above the surface of the work, the precise distance depending upon the size and shape of the weld.

The determination of the size and number of studs to use, is a matter of calculation and experience. The combined strength of the studs should be sufficient to develop the full strength of the cast iron. As steel has approximately four times the strength of cast iron, the ratio of the total cross-sectional area of the studs on one side of the weld, to the cross-sectional area of the cast iron, should be approximately one to four. The technic of the process is ordinarily better when large studs are employed for large sections and smaller studs for smaller sections.

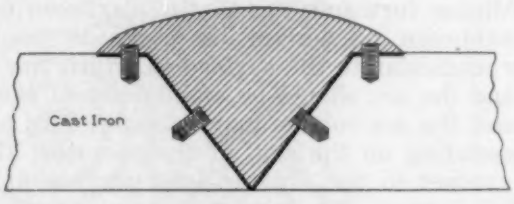


Fig. 2
Cross Section of Studded Joint

The usual welding procedure is to first weld around each stud, forming a cone shaped pad of deposited metal and to then weld from pad to pad until the entire face of each side of the V is covered with steel filler metal. Finally, the space between those faces should be filled in by welding. It is sometimes recommended that the filling in between faces be done by laying in beads along the length of the weld, rather than cross-wise, with the idea that this may reduce the contraction stresses across the weld. This method is liable to reduce somewhat the tensile strength across the filler metal itself, but as its strength is ordinarily much higher than that of the cast iron base, a small reduction is not serious.

It appears that Mr. Joseph McAllister of the New York Central Railroad was the first to employ studding in the welding of cast iron and he has employed it consistantly on much cast iron work for a number of years.

The first notable example of studding which has come to our knowledge was the welding of engine cylinders and other cast iron parts of the damaged German ships at the Navy Yards at New York and Philadelphia during the War. This work was investigated by the late Mr. D. H. Wilson and performed under the supervision of himself and Mr. McAllister.

It might, at first thought, appear that weakening of the casting

by the stud holes, would be a serious disadvantage. However, the application of a proper amount of filler metal around the studs will more than offset this weakness. Mr. McAllister has prepared test pieces by inserting studs in cast iron bars. In these test pieces, the failure occurred well beyond the studded sections.

It is Mr. McAllister's recommendation that a sufficient number of studs be placed along each side of the weld, so that the combined shearing strength of the studs will at least equal the tensile strength of the cast iron section. It is his opinion that the studs should not project more than ½" above the surface of the casting regardless of the thickness. His welding procedure consists in first depositing a circular pad of metal around each stud, then depositing metal to connect these pads until finally he has a layer of deposited metal covering each side of the V. The subsequent making of the welded junction between the two steel covered faces is comparatively simple.

Mr. McAllister further states that if maximum penetration and minimum oxidation are desired, the electrode should at all times be held perpendicular to the surface on which the metal is being deposited and the arc should be maintained as short as possible. In some cases the arc voltage may be maintained as low as 15 to 18 volts depending on the skill of the operator. This manner of operation exposes to the arc the least surface of electrode and consequently insures the maximum concentration of current energy; it also reduces the surface of molten metal exposed to oxidation.

The Allard Method of Welding Cast Iron

In a paper published in the January issue of the "Proceedings of the American Welding Society", Mr. A. L. Allard of the Westinghouse Company recommends a slightly different method of studding. An abstract of certain sections of his paper follows:

"A square groove is chipped along the line of the break or crack. The size of this groove depends upon the thickness of the casting and is usually ¼", ⅜" or ½" square".

"The groove is then filled up by welding until it ie flush with the face of the casting".

"Locate and set the first stud in the casting as close to the crack as practicable. The location of the stud is determined by the thickness and shape of the casting and the size of the stud. The size and number of studs is dependent upon the volume of added metal required to give the necessary strength. Studs should be long enough to extend through the first layer so that good fusion can be obtained between them and the second layer. The studs should be set as close to the edge of the break and to each other as practicable".

"Weld around the first stud with a sufficient number of rows of deposit to reach to the center of the break, as shown at X in Fig. 3.

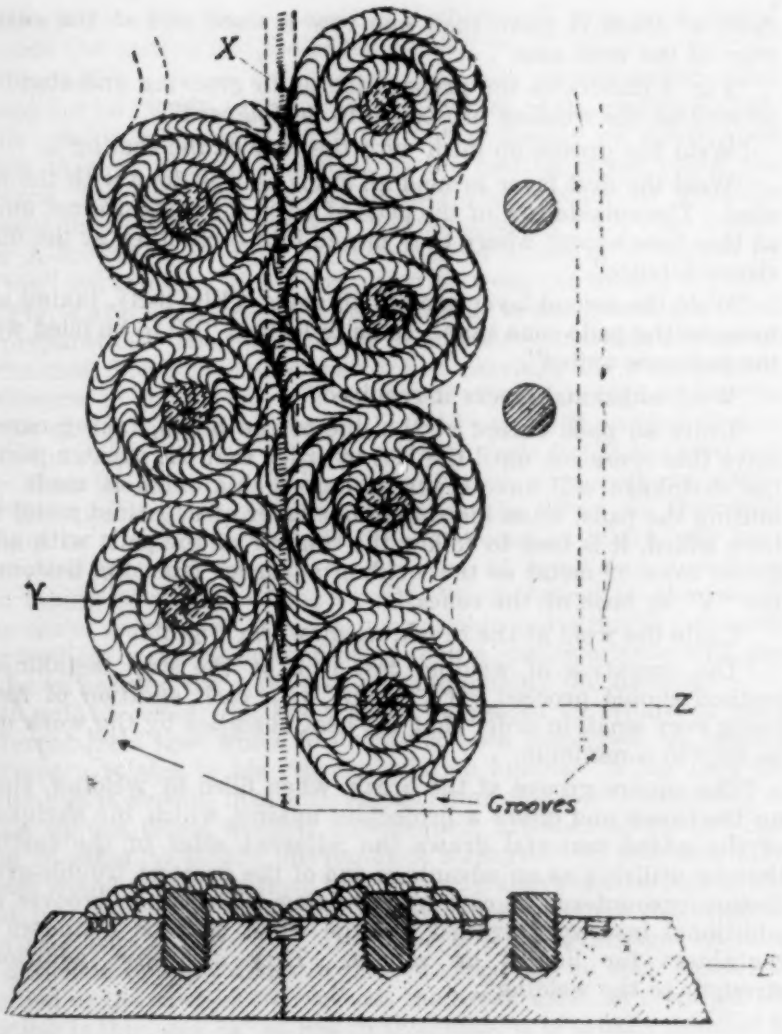


Fig. 3
General Procedure of the Allard Method of Welding Cast Iron Parts.

This procedure will determine the area covered by the metal surrounding one stud and will aid in locating the remaining studs".

"Locate and set the necessary number of studs to complete the job".

"Chip or grind grooves, as shown in Fig. 3. These grooves may be either square or semi-circular, although ¼ inch square grooves are used most frequently. Grooves should be placed between the

rows of studs if more than one row is used and at the outside edge of the weld area".

"Fig. 3 illustrates the preparation as to grooving and studding, as well as the welding procedure to be followed".

"Weld the groves up flush with the face of the casting".

"Weld the first layer around all studs as was done with the first stud. The outside row of the pads of adjacent studs are not united at this time except where they merge into each other at the outer circumference".

"Weld the second layer around all studs, (Fig. 3-B), taking care to make the pade cone shape, so as to leave a "V" to be filled when the pads are united".

"Weld additional layers if required".

"Unite all pads except at the line of the break, taking care to leave this operation until the last in order that the greater part of the shrinkage will have occurred before this union is made. In uniting the pads, when more than one layer of deposited metal has been added, it is best to follow the contour of the pads with additional rows of metal as the welding advances from the bottom of the "V" or base of the cones."

"Unite the weld at the break, as shown in Fig 3".

"The operation of welding cast iron by the steel metallic arc method should proceed very slowly, with each addition of metal being very small in order that the heat absorbed by the work may be kept to a minimum".

"The square groove at the break, when filled by welding, closes up the break and offers a projection against which the shrinkage of the added material draws the adjacent sides of the casting, thereby utilizing as an advantage one of the greatest trouble-given factors encountered in cast iron welding. The other grooves are additional insurance against leakage when used on cylinders or containers for liquids or vapors. They also give additional strength to the welding".

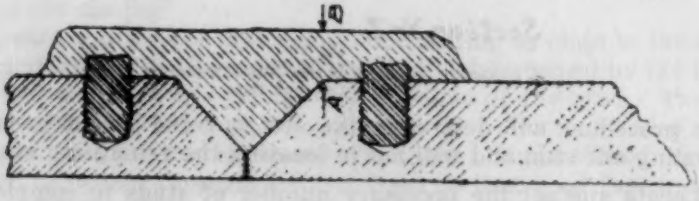


Fig. 4

"The method of "V'ing" out the casting, as shown at "A" (Fig. 4), was inherited from the practice followed in gas welding and may be followed when welding sections of casting in which the

carbon is found to be in a condition which will give good fusion between the casting and the added metal."

"The heavy sections of graphitic cast iron usually encountered should not be "V'ed" out, because the surface of the casting, which chills quickly when cast, affords a better quality of metal upon which to weld than is presented as the casting is cut below the surface. As the cut becomes deeper the amount of graphite present in the metal increases. Examination of "A", Fig. 4, Section A-B, will show that no increases of strength is gained by "V'ing" out in cases where the fusion between the metals is poor."

"Fig. 4 also shows another disadvantage to the beveling method of preparation. There is without question considerable shrinkage of the steel filler material no matter how carefully the work is done. Reference to the sketch will show that the shrinkage draws the bevels of the casting against the beveled boss of the added section, with the result that the pressure exerted tends to lift the steel section from the casting and this, in fact, takes place in many cases."

"The practice as outlined, will keep the effect of shrinkage strains to a minimum by affording a procedure which will keep the work cool and by affording means of equalizing, balancing and taking advantage of the stresses which cannot be eliminated. The use of small wire, as low as permissible and straight line welding without weaving or oscillating of the steel electrode will also assist in keeping the work cool and minimizing the stresses."

It will be noted that the method suggested by Allard is quite different from that which has hitherto been employed. A leading difference relates to his recommendation against "V'ing" out the break. It is obvious that with Allard's procedure, it is necessary to build up the filling metal a considerable distance above the cast iron in order to obtain the requisite strength. In fact this filler metal would ordinarily have to be built up above the surface of the cast iron to a height equal to at least one third the thickness of the cast iron itself. This of course is a disadvantage where it is desirable to keep within a limited space and in such cases, the method of beveling or "V'ing" out the break must be used. If the casting is thin, say ¼" or less in thickness, it is usually possible to obtain good fusion without "V'ing" out and without studding.

Holslag Method of Welding Cast Iron

Mr. C. J. Holslag of the Electric Arc Cutting and Welding Company in his instruction Handbook describes methods of welding cast iron. A quotation follows:

"Welding Cast Iron"

"*First Case.* Simply as a means of filling in, or building out, where grinding is the only machining necessary. Clean out the spot to be welded by chipping or grinding, so that all dirty, oily, sandy, or porous metal is cleaned away and a reasonably bright

metal foundation is provided for the weld. Weld with either steel or cast iron electrode according as to whether a reasonably hard or a very hard surface is wanted after grinding. The steel gives a hard surface and the cast iron a very hard surface. Care must be taken in using the cast-iron electrode that the quick cooling does not catch gas bubbles in the weld leaving holes after finishing. The steel causes no such trouble, but if one or two imperfections show, a peening hammer will close them up".

"*Second Case.* Welding cast iron where tensile strength is required, but no resistance to bursting pressure will be experienced, i. e., welding broken machine-parts, bed-plates, etc. In general where no undue strain results and the part was originally broken by some accident which will hardly happen again in the same place, first, "V" out wide enough so that the electrode can be held at approximately right angles to either face of the "V". Weld the two faces of the "V" separately with steel, using great care to have the steel united to the face as the arc progresses and not let any of it run down ahead of the puddle; weld from the bottom up, and if any of the deposited metal does get away, stop and chip it off. After the two faces are successfully covered, it is extremely easy to make a good weld from the steel faces, using steel or cast iron in the "V".

"*Third Case* Welding cast iron where heavy bursting pressure is to be met or great tensile strength is required. Use steel studs in single or double row either side of the "V", i. e., from 1 in deep on the upper half of the "V". The studs to be $\frac{3}{8}$ in. to $\frac{3}{4}$ in. in diameter, depending on the size of the work, to be screwed into a tapped hole from $\frac{1}{2}$ in. to 1 in. deep, according to the thickness of the work. Saw off $\frac{1}{8}$in. to 3-16 in. above the surface of the work. *First*: Carefully weld around the studs so that the studs are part of the cast iron, then weld diagonally as in lacing a shoe across the weld from stud to stud and finally finish as with a pad over all completely covering the studs. In general, studs of steel are needed in a number so that their cross-section in square inches multiplied by 60,000 lbs., (their strength), equals the cast iron section in square inches, multiplied by 18,000. lbs. (its strength), i. e., the steel studs should have one fifth the area of the cast iron to give a 100 per cent job."

"The first welding from stud to stud draws the casting together into original contact, especially if a small amount of the original break is left intact at the bottom of the "V". This can be done except in the instance where the piece breaks out and is lost, as in engine cylinder wrecks. A bottom of copper forced in with an air hammer should be used so that for subsequent machining the chilled cast iron surface under the weld will not be met."

"*Fourth Case.* Welding cast iron for subsequent machining through the weld. In all of the foregoing cases the weld may or

may not be machinable, but the chilled layer of cast iron directly under the weld will seldom be machinable except for very thin pieces, due to the cast iron having been heated and chilled quickly leaving the carbon in the combined state.

"To remove this hardened layer when welding with steel and to remove the entire hardness of the entire section when welding with cast iron, the following procedure must be gone through. Where the piece is of such shape that it can be welded cold, reheating and annealing will make it machineable, i. e., any time after welding, bring the weld and adjacent cast iron up to a little better than red heat and allow it to remain there from two to ten minutes depending on the size of the piece, then cool slowly by burying in warm sand, fire-clay or limestone. Where piece is of such shape that the cooling strains when welding quickly, as in electric welding, would warp or break the piece, preheating is necessary, but only to a small degree, i. e., less than red heat, in order to save the piece from breaking while welding. Directly after welding, bring the weld and adjacent cast iron up to better than red heat and anneal as before. This method results in either steel or cast iron electrode applied to cast iron being entirely machineable and in the case of cast iron electrode results in a weld which is not discernable from the original cast iron by either physical or chemical analysis."

"In general, cast iron containing small amounts of steel, i. e., so called semi-cast iron, is much easier to weld than pure cast iron. Generally, the only welding done on cast iron, except in the case of accidents, is where the original cast iron is defective because of sand holes, porus spots or other troubles in casting: this slag must be entirely removed before satisfactory welding can be expected".

"Usually the cast iron electrode, while it becomes more fluid than steel under the arc, cools quicker than steel and from the outside inwards, because steel cools by the conduction of the heat in weld into the adjacent metal from the inside outwards and hence with cast iron there is more chance of voids and gas bubbles being left in the weld and some sort of flux to prevent this, is necessary in depositing cast iron. Desirable ingredients in such flux being:

1. Quieting reagent
2. Quick floater of dross to the surface
3. Oxygen and nitrogen protector, so that bubbles, films or needles of oxide and nitride are not left in the weld.
4. Protection against rapid cooling of surface."

Hardness at Weld

When cast iron is welded by the metallic arc process, without preheating, there is usually a layer of extremely hard metal at the junction of the filler and base metal. This is sometimes so hard as to be un-machineable, except by grinding. This hard layer is ascribed principally to the formation of what is known as "white iron".

This "white iron" is formed when the molten surface layer of cast iron is chilled by the cold mass of metal lying back of it. In "white iron", which is extremely hard and brittle, the carbon is held in solid solution. In this form the carbon is present as combined carbon.

Furthermore a portion of the steel filler metal, while molten, absorbs some of the carbon from the molten cast iron, becoming high carbon steel and is also quickly cooled, giving in effect a layer of quenched high carbon steel.

It necessitates placing the casting in a furnace or some equivalent also be a contributary cause of the extreme hardness. In fact it appears that the extreme hardness often experienced is due to something more than simply the formation of white cast iron. Methods of research to determine the true cause and possible methods of overcoming this hardness are of much importance and have been considered by the Committee.

Preheating and Annealing

The best method of avoiding the hard zone from the standpoint of metallurgical results, would seem to consist in preheating the casting before welding, or annealing it after the completion of the weld. By either preheating or annealing, if properly done, the hard zone can usually be avoided, without prejudice to the quality of the weld. The unfortunate circumstance is that either preheating or annealing is expensive and requires special equipment. It necessitates placing the casting in a furnace or some equivalent process and may result in warping the structure.

If no furnace is available, a temporary one may be built of fire bricks and the casting heated by a coke or charcoal fire. Care should be exercised to see that all parts of the casting are heated uniformly and it is best to heat it up rather slowly. For preheating, a temperature of about 500° C (corresponding to a "dull red" heat) should be employed. The weld should be made promptly and the casting allowed to cool down very slowly in the furnace. If the casting has been heated with a charcoal or coke fire it should, while cooling, be covered with ashes and ambers.

For annealing after welding, which is desirable if the very best results are wanted, the casting should be heated to a "red heat", (about 850° C) and then allowed to cool very slowly in the furnace.

Inserting Copper Strips

When only one side of a weld need be machineable, the following practice is sometimes adopted. The break is "V'd" out, with the apex of the V on the side that must be soft. Then a strip of copper is laid on the V and peened in. The steel filler metal deposited in the V above the strip of copper. The copper filler is of course readily machinable.

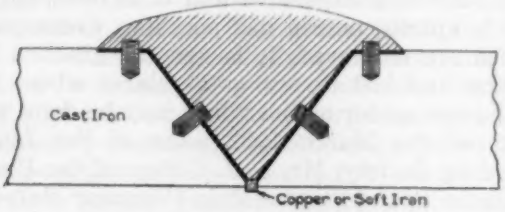


Fig.
Cross Section of Joint showing Insertion of Copper Strip.

Reversed Polarity

In ordinary metallic arc welding of *steel*, the work is connected to the positive terminal of the welding current supply source and the electrode to the negative. As considerably more heat is generated at the positive end of an arc than at the negative, it has been proposed that in the welding of cast iron the polarity be "reversed", making the work negative and decreasing the temperature at the point of application of the arc. However, even though the *Local* temperature is decreased, a certain amount of the iron must be melted in order to obtain a weld and chilled iron is bound to result. On the basis of this reasoning "reversed polarity" should not be particularly affective in preventing the hard zone. Nevertheless some welding people of wide experience claim that softer welds are obtained in cast iron welding when "reversed polarity" is employed.

Special Electrodes

Electrodes of a wide variety of compositions and with various kinds of fluxes and some with flux coverings, have been recommended and used for welding cast iron. The Committee is not prepared to say how effective these electrodes are, nor which is best.

Nickel electrodes are quite widely used in filling in blowholes in castings, for example, in automobile cylinders. Nickel possesses the advantage of not absorbing carbon from the cast iron. Hardness is thus avoided and a machineable joint is obtained. However, there is liable to be a small zone of chilled cast iron around the joint. It would appear that nickel should not be employed in a weld which will be placed in tension or shear.

The Committee found that joints made with a nickel electrode using reversed polarity were not dependable as the filler metal consisted mainly of blowholes and gas pockets.

Phosphor Bronze electrodes are reported to have been employed with some success in producing machineable cast iron welds.

Monel Metal and other copper nickel electrodes are said to give a soft weld in cast iron and one of much strength. However these

electrodes are relatively expensive and it is believed that the deposited metal is apt to contain gas pockets. Consequently, where these electrodes are employed, it is general practice to use them only on the first and last layers, or at places where holes are to be drilled. The remainder of the filling may be done with steel.

On page 39 of the March 1922 issue of the Journal of the American Welding Society, Mr. L. J. Cullen of the Port Richmond plant of the Staten Island Shipbuilding Company states as follows:

"The monel electrode, which was used is a flux coated wire and at no point did the added metal separate itself from the cast iron. The completed casting was very easily machined, not a tool being broken, as has been nearly always the case in the past when machining deposited metal from a steel electrode."

Mr. Cullen here refers to the repair of large cast iron bracket from which a large piece had been broken. 150 amperes with a 5-32 in. electrode were used.

Comments of Noted Experts on the Welding of Cast Iron Without the Use of Studs, Preheating or Annealing.

Mr. O. H. Eschholz of the Westinghouse Electric and Manufacturing Company is quoted as follows:

"For most purposes, we find 5-32 in. or 3-16 mild steel electrodes to be satisfactory with welding currents of respectively 150 to 175 amperes. When welding thin material, however, ¼" or less in thickness, it is available to use smaller electrode diameter and a lower current, so that it is our practice to employ ⅛" diameter and about 100 amperes. We have welded preheated cast iron successfully, employing lime-coated cast iron electrodes 3-16 in. in diameter with about 150 amperes. We find that on coating high carbon steel with lime, that the deposit will be free from the usual surface pin and blow holes."

Mr. C. J. Holslag of the Electric Arc Cutting and Welding Company has contributed the following information on the subject of Cast Iron Arc Welding.

"First in order is the copper-nickel electrode, which is similar to the plain monel metal electrode. Deposit from this copper-nickel electrode have the property of being machineable when welded cold. The weld has the tensile strength of steel, but is not as reliable and it is not usual to fill the entire V in a big job, but simply to employ it for the first layer and the last layer, or a joint layer, or where a hole must be drilled, in order to have the machineable properties of this electrode, coupled with the strength of a special electrode for cast iron, which is of mild steel with a heavy carbon coating, so that much of the carbon burned out by the arc restored."

"In the carbon arc welding process as applied to cast iorn, a gun-metal cast iron filler rod is used. The method must be the same as in gas welding, in which case the results are the same.

This last simple fact is now overlooked and 99 out of 100 persons interested in welding will say "Electric welding is hard, whereas gas welding is machineable, entirely overlooking the fact that it is the preheating and annealing that make gas welding machineable and that cast iron so welded electrically is equal to the gas process. Without preheating, the entire gas weld and moulded section would be glass-hard in its entirety."

Comments from several persons who have had some experience with cast iron arc welding are given herewith.

Mr. B. C. Tracy of the Power and Mining Department of the General Electric Company states:

"The application of electric welding to certain cast iron parts is fast becoming a recognized method by which to effect repairs in an efficient and economical manner."

"It should be appreciated that the electric welding method should not be considered a cure for all ills as regards defective or broken cast iron parts since it may be that the making of a new part in some instances would prove to be most desirable and until this condition is appreciated electrical welding will not be able to make the showing of which the are is capable."

"It has been the practice for the past eight years to weld heavy broken cast iron sections where the operation would not require the parts to be oil or steam tight. And in this respect it might be well to mention that the method of studding the parts preparatory to welding was never used, (on any of the large number of cast iron welding jobs with which I was associated during that period), primarily because of the success without its use, also because of the high cost of labor in preparing and inserting the studs in the welded section. In fact, in most all instances the cost of drilling, tapping, applying and cutting of the studs will be higher than the actual cost of welding."

"I believe an investigation to determine, when, where, and why studs should be used in making a cast iron weld will be welcome information to a great many users of arc welding equipments. It is not uncommon to witness in one locality two different users of arc welding machines, using widely different methods of welding the same job. I mean, particularly, heavy sections where one will be employing studs and the other will not. No doubt each believes he is using the best method of repairs, but surely one must be the best. Why is it?"

"Several notable instances are given below, where large sections of cast iron were welded, large savings being effected in each case:

"The first is a large gear for punch and shear machine operating in a railroad repair shop. The gear was broken in service and repaired by the electric arc without studs, at an approximate cost of $13.00 including labor of preparing parts for welding, and labor, material and current consumption in welding."

"The second is a large wheel lathe chuck which was damaged by accidently dropping a 4 in. brass plug in the gear travel. The lathe was out of operation only 24 hours and put back in service at an approximate cost of $20.70."

"With some care, a conscientious operator and traveling over the parts at a rather slow rate, I believe satisfactory results will usually be obtained."

"I believe you should also advise the prospective user of arc welding equipments as applied to cast iron welding that the limitation of cast iron welding is a factor that is dependent upon the quality of the filling material, the manipulation of the arc, some good sound judgment and his willingness to attempt it."

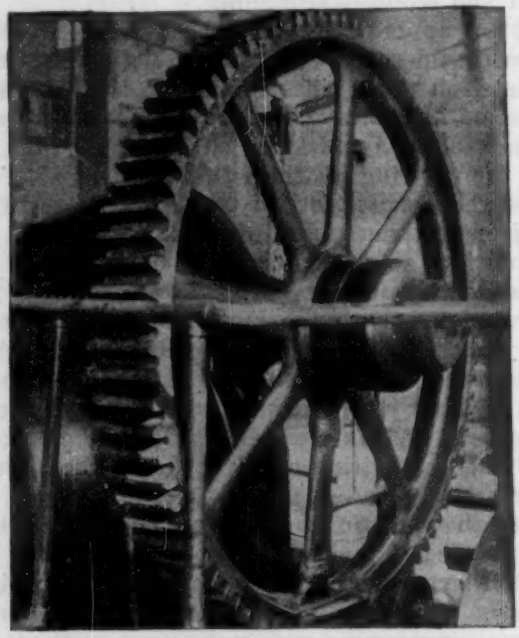


Fig. 5

Repared with 5-32 in. bare electrodes using 150 amps. Each weld was reinforced approximately 3-16 in. at the center of the V grove.

Mr. James H. Davis, Manager of the Maryland Welding Company, is quoted as follows:

"If a person were sure he was going to make a job of it he would not use studs along the edge of the cracks as the placing of studs is really an admission that he wants the iron or steel to weld too, in order to make the job hold. You can make a job hold with studs, but you are only welding the *studs* and in case of a steam

tight, water tight or air tight job, it will break around and between the studs when contraction takes place.

We do some cast iron welding now, but always with the agreement that they pay for it whether it holds five years or five seconds. In my opinion, cast iron welding is always problematical;

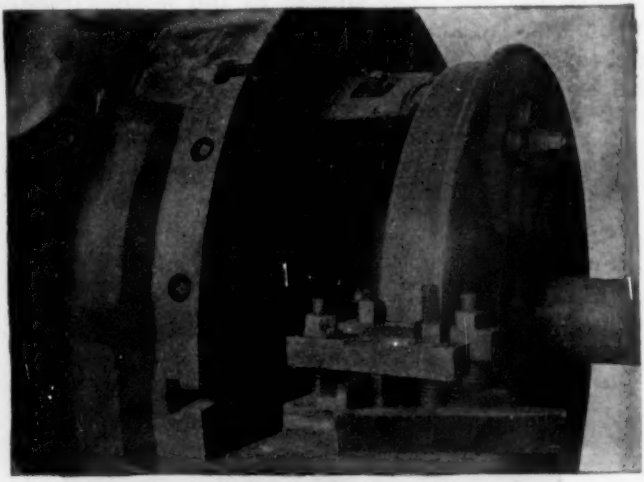


Fig. 6

Repaired with 5-32 in. bare electrode using 175 amperes. The welding process was continuous, no stops being allowed from start to finish

Fig. 7

Repaired with 5-32 in. bare electrode using 175 amperes. 1-4 in. studs were used without "V'ing" out the crack. Each weld was heavily reinforced. This cylinder has been in service three years and is still in service.

it may be a very good job in every respect and then again the grade of iron may be such that the best welder cannot do anything with it."

Mr. J. C. Horstman, Manager's Office, General Electric Company, Schenectady, is quoted as follows:

"It is possible to weld cast iron without studs if the weld section is not heated too hot. The success of the welding operation depends upon the size and shape of the casting and the operator's skill in choosing the proper current. A long arc and high voltage will tend to blow the molten metal away from the weld besides

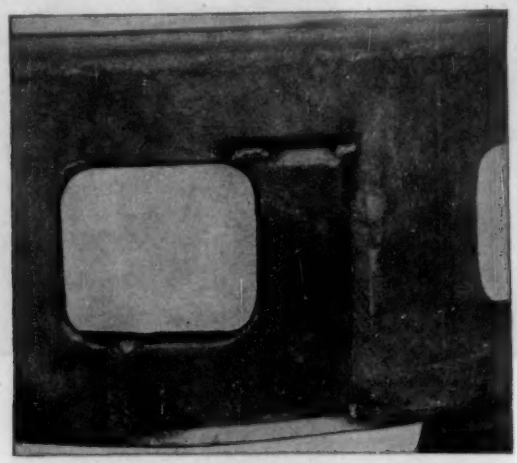


Fig. 8

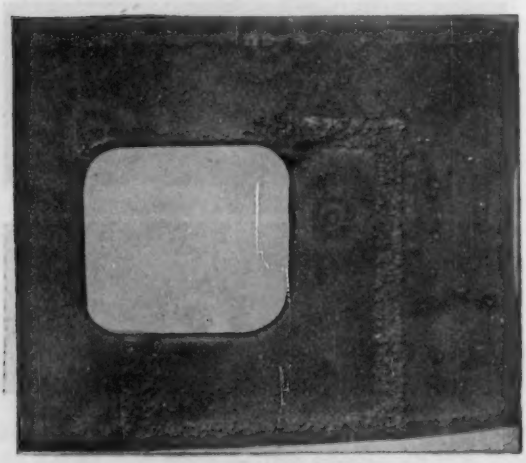


Fig. 9

Figs. 8 and 9 show the application of steel patches to repairing cast iron breaks.

unnecessarily heating the casting. No haphazard method will give consistent results.

When welding where contractions will draw the V opening together during the welding process, a wedge should be used to keep the edges as far apart as possible so that when the filler metal

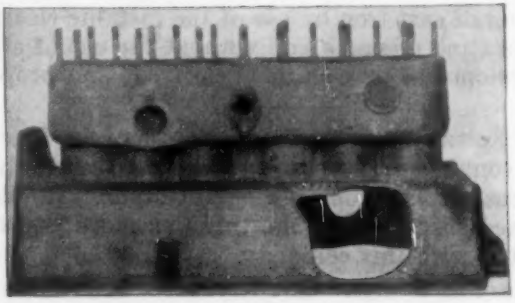


Fig. 12

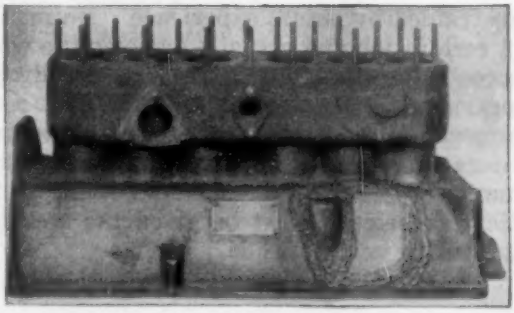


Fig. 13

Figs. 12 and 13.—Cast iron engine cylinder repaired by the electric arc using studs.

cools, the original size and shape of the casting may be resumed gradually without causing a fracture through the cast iron.

The welder must see the job and must be able to correctly analyze the conditions existing in order to specify the method to be used to secure the desired results."

Mr. P. O. Noble, Welding Engineer of the General Electric Company, is quoted as follows:

"In the present state of the art, we cannot make the general

statement that we can weld cast iron with the metallic arc welding process. We cannot be sure that a union between the cast iron and the added steel will be obtained or that this union, if obtained, will be sufficiently strong to withstand the strains incident to contraction of parts on cooling.

It is therefore necessary to use studs and the strength of the weld should not be considered to be more than the strength of the studs.

The welding of cast iron by use of the metallic electrode process, without preheating of parts and without the use of studs, depends upon the development of a suitable electrode and proper procedure in its use."

Mr. W. L. Lowns, Shop Supervisor of the Troy Electric Welding Company is convinced that cast iron can be electrically welded and welded successfully without the use of studs. He states that he has never used studs during the three or more years that he has been connected with this company.

Mr. Lowns uses a high current value when welding cast iron, 150 amperes being the average current used, although 175 amperes is frequently employed. Whenever it is necessary to minimize expansion and contraction stresses, the welding operation should proceed slowly, but the usual current is needed in any case to cause the filler metal to fuse with the base metal to a sufficient depth.

Welders are trained by actual experience. No man can be told how to weld a certain job and actually perform the welding operation with successful results unless he has already completed a similar job previously. Mr. Lowns believes that certain fundamentals of arc welding can be learned from reading various books and certain literature, such as is being compiled by the Cast Iron Welding Committee, but the fact should not be overlooked that certain practical experience must be given the welder before the results desired can be accomplished.

ACKNOWLEDGEMENTS

In concluding this first part of his paper, the Author wishes to acknowledge the hearty cooperation and assistance which he has received from all the members of his Committee. Throughout the course of the work of conducting the researches, which will be described in the second part of the paper, as also in the preparation of the paper itself, the Author has been guided by the knowledge and experience of his colleagues.

The personnel of the Committee was as follows:

J. W. Belanger of the Power and Mining Commercial Dep't of

the General Electric Company.

T. S. Fuller of the Research Laboratory of the General Electric Company.

H. M. Hobart, Chairman of the Electric Arc Welding Committee.

J. C. Horstman, Welding Specialist in the Manager's Office of the General Electric Company.

F. P. McKibben, Head of the Civil Engineering Department of Union College.

J. McAllister, General Foreman of the N. Y. C. R. R Shops, West Albany.

P. O. Noble, Welding Engineer of the General Electric Company.

J. M. Sampson, Superintendent of the Foundries of the General Electric Company.

B. C. Tracey, Power and Mining Engineering Dep't of the General Electric Company.

H. A. Winne, Power and Mining Engineering Department of the General Electric Company.

G. W. Wright of the Testing Laboratory of the General Electric Company.

W. L. Warner, Secretary.

W. H. Namack, Chairman.

The Author furthermore wishes to acknowledge the assistance of the American Rolling Mill Company who made most of the chemical analyses appearing in the second part of the paper.

BIBLIOGRAPHY

LIST OF REFERENCES ON ELECTRIC WELDING OF CAST IRON, 1917-1921.

1921

CANDY, A. M.
Solving Some Arc Welding Problems.
FOUNDRY, v. 49, p. 179-86, March 1, 1921.
IRON TRADE REVIEW, v. 68, p. 829-35, March 24, 1921.
Considerable attention to cast iron.

REDDIE, W. W.
Arc Welding Equipment in the Foundry.
ELECTRICAL JOURNAL, v. 18, p. 96-99, March 1921.
Equipment and methods.

VIALL, ETHAN
Electric Welding, 1921. McGraw-Hill Book Company
Has some material on welding Cast Iron.

ANONYMOUS
How to Weld Cast Iron Electrically.
FOUNDRY, v. 49, p. 68, January 15, 1921.
Welding Heavy Section by the Electric Arc.
CANADIAN MACHINERY, v. 26, p. 32-33, 46, July 14, 1921
Some information on Cast Iron Welding. Abstract of an instruction book published by the Electric Arc Cutting and Welding Company.

1920

CARPMAEL, H.
Electric Welding and Welding appliances, 1920, D. Van Nostrand Company, New York.
Welding of Cast Iron, p. 36.

KENYON, O. A.
Welding an Engine Cylinder from the Inside.
INTERNATIONAL MARINE ENGINEERING, v. 25, p. 188-90, March, 1920.
Twenty-five Patches Welded on interior of Cylinder, by Electricity without distorting bore of Cylinder.
Notable example of Cast Iron Welding.

KENYON, O. A.
Welding Cast Iron with the Electric Arc.
IRON AGE, v. 105, p. 12-16, January 1, 1920.
Typical illustrations of welding methods and suggestions in regard to overcoming brittleness and cracking.

KENYON, O. A.
Welding the Interior Surface of a Cast Iron Cylinder.
MACHINERY, v. 26, p. 642-3, March, 1920.
Discusses difficulties to be overcome and methods of welding.

KINKEAD, R. E.
Electric Arc Welding to Steel, Malleable Iron and Gray Iron Castings.
IRON AGE, v. 106, p. 534, August 26, 1920.

KINKEAD, R. E.
Welding Cast Iron with the Electric Arc.
WELDING ENGINEER, v. 5, p. 23-24, August 1920.
Short account from a paper before the American Welding Society.

KNOX, H. G. and OWEN, J. W.
Repairing Cast Iron Cylinders by Welding.
INTERNATIONAL MARINE ENGINEERING, v. 25, p. 340-46, April, 1920.
Illustrated descriptive article.

SPRINGER, J. F.
Electric Welding of Cast Iron.
RAILWAY AND LOCOMOTIVE ENGINEERING, v. 33, p. 53-54, February, 1920
How cracked Cast Iron front end of locomotive was welded.

VIALL, ETHAN,
Examples of Arc Welding Jobs.
AMERICAN MACHINEST, v. 53, p. 719-25, October 14, 1920.
Discusses the method of welding the Cylinders on the German interned ships and the strength of the Cast Iron Welds.

ANONYMOUS
Restoring Cast Iron Cylinder by Electric Welding.
MARINE NEWS, v. 6, p. 97, February, 1920.

1919

KINKEAD, R. E.
Arc Welding Makes Good in the Foundry.
IRON TRADE REVIEW, v. 65, p, 985-86, October 9, 1919.
FOUNDRY, v. 47, p. 752, October 15, 1919.

MARQUAND, H. S.
Electric Welding. Part VII. Welding of Cast Iron.
ELECTRICIAN, London, v. 83, p. 17-19. A Review.

1918

BOWERS, B. W.
Electric Arc Welding Applied to Cast Iron.
FOUNDRY, v. 46, p. 158-59, April, 1918.

ESTEP, H. C.
Welding Tool vs. the Sledge; how interned Gerran Liners Wrecked by Prussian Vandalism were repaired.
IRON TRADE REVIEW, v. 62, p. 57-72, January 3, 1918.

ANONYMOUS

1917

Welding Cast Iron with the Electric Arc.
RAILWAY AGE, v. 64, p. 1247-9, May 17, 1918.
Experience of the New York Central.

BALTES, H. A.
Repairing a Large Casting by Electric Arc Welding.
FOUNDRY, v. 45, p. 120-1, March 1917.

BARDTKE
Electric Welding of Castings, with special reference to Cylinders (In German)
GLASERS ANNALEN, December 15, 1917, p. 148-52.

CUMMING, J. *D.*
Welding a Large Cast Iron Spider.
AMERICAN MACHINIST, v. 47, p. 136-37, July 26, 1917.
Gives definite data and the way various troubles were overcome.

JESSOP, E. P.
Repairing German Vandalism by Electric Welding.
JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS, v. 29, p. 639-54, November, 1917.
INTERNATIONAL MARINE ENGINEERING, v. 23, p. 122-27, March, 1918. Condensed.
Welding Cast Iron Cylinders and strength of such Welds.

KINKEAD, R. E.
Welding Cast Iron with the Electric Arc.
WELDING ENGINEER, p. 27, v. 2, December, 1917.

KNOX, H. G.
Welding Main Engine Cylinders.
JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS, v. 29, p. 655-60, November, 1917.
Both Acetylene and Electric Arc Welding.

MAWSON, R.
Arc Welding on Malleable Iron.
AMERICAN MACHINIST, v. 46, p. 219, February 1, 1917.
Practice of the Dayton Malleable Iron Company, with an outfit of the Lincoln Electric Company.

SCHNEEBERGER, J.
Welding a Cracked Cylinder.
RAILWAY MECHANICAL ENGINEER, v. 91, p. 322, June, 1917.

MEMORANDUM

Cast Iron Welding by the Oxyacetylene Process.

S. W. MILLER

While other gases than acetylene are occasionally used with oxygen for welding, yet they do not give as high a flame temperature and so are slower in their action and need not be here considered, especially as the vast majority of the work is done with acetylene.

Flame; Combustion; Oxidation

A flame is caused by the rapid combination of some element with oxygen, of which gas, the air contains roughly one fifth by either volume or weight. The rest of the air is composed of nitrogen, a very inert or inactive gas chemically, * and which has nothing to do with the making of a flame. Combustion and oxidation are two terms used in talking about the combination of oxygen and another element. Combustion is limited to the cases of rapid combination, while oxidation is a more general term and may be properly used in the case of any combination of oxygen with another element. One of the most common examples of slow oxidation is the rusting of iron when exposed to the air.

Combinations of oxygen and other elements are called oxides, so that rust is oxide of iron. All the common metals, such as copper, aluminum, zinc tin, lead etc., combine with the oxygen of the air at ordinary temperatures, but none of them so rapidly as iron. The tarnishes on their surfaces are really oxides of the metals.

Rapid oxidation is combustion, or burning. Iron may burn under proper conditions, such as when it is being cut with a cutting torch and the sparks that fly while welding steel are particles of burning iron.

We all know that burning produces heat and it is evident that the more rapid the burning the greater the amount of heat produced in a given time, because it takes only a certain amount of oxygen to change a given amount of iron into iron oxide and the total heat produced is the same whether it is done fast or slowly. If it occurs slowly, as in rusting in the air, there is no noticable increase in temperature, because the heat is carried away by the air as fast as it is generated. But if it occurs rapidly enough, the heat cannot be carried away as fast as it is generated and the iron and air around it will get hotter.

It is also evident that the more oxygen we can get to the iron or any fuel in a given time, the more rapidly it will burn. Putting

*There are very small quantities of other gasses, but as they amount altogether to only a fraction of one per cent and are more inert than nitrogen, we need not consider them

on the draft in a furnace, or using the blower on a smith's forge does just this, making a hotter fire.

Now while iron will burn, it is not used for fuel and the fuels we commonly use are coal, wood, coke charcoal and city or natural gas. These all contain large amounts of the elements carbon or hydrogen, or both. Hard coal and charcoal are nearly pure carbon, while the other fuels contain both carbon and hydrogen. The carbon and hydrogen are chemically united in various ways, but when they burn, they do so as carbon and hydrogen. So in any fuel, we need consider only these two elements.

Welders are familiar with hydrogen, so much used for the preheating gas in cutting It is a gas and the lightest one known, being much used to fill balloons and air ships. Carbon never exists as a gas, though many gases contain it in chemical combination. When a gas burns, it is because its carbon and hydrogen combine with oxygen from some source, which as before explained, results in oxides of carbon or hydrogen.

There are two oxides of carbon, which are called carbon monoxide and carbon dioxide. The first term means that car bon is combined with one part of oxygen and the second that it is combined with two parts of oxygen, so that carbon dioxide contains twice as much oxygen as carbon monoxide. Further, carbon monoxide is the "firedamp", formed in coal mines by various causes and which is so much dreaded because of its explosive properties when mixed with air. Its chemical symbol, really a sort of chemical shorthand, is CO, meaning 1 part of carbon (C) and 1 part of oxygen (O).

Carbon dioxide is sometimes called carbonic acid gas. It is used mostly to make charged water from which soda water is made. The fizzing of the water is used by this gas escaping when the pressure on the water is released. Its chemical symbol is CO_2 meaning that it contains one part of carbon and two parts of oxygen. * The hydrogen in burning is oxidized to water, or rather water vapor, or steam, as the flame temperature is so high that water, as such, could not exist. The chemical symbol of hydrogen is H and of water, or steam, H_2O, meaning that two parts of hydrogen combine with one part of O to make water.

In the burning of carbon, it is never possible to produce CO_2 directly and CO must always be the first result. This CO is then oxidized, or burnt and CO_2 is formed.

Acetylene is a gas composed entirely of C and H. Its symbol is $C_2 H_2$, (two parts of C and two parts of hydrogen). By *weight*, it contains 92.3 per cent of carbon and 7.7 per cent of hydrogen. Welders are familiar with its sweetish odor and the smoky flame

*A more accurate statement is of course that one atom of C and one atom of O unite to make one molecule of CO and one atom of C and two atoms of O to make one molecule of CO_2. Those interested enough can find full explanation of the subject in any elementary chemistry. There is not room here to do more than give a fairly correct picture of what occurs.

with which it burns in a torch before the oxygen is turned on, which is because it does not get enough oxygen from the air to burn it and some of the carbon in it is deposited as soot. But if a proper burner is used, it gives a beautiful, intensely white flame, entirely free from soot. In welding, practically pure oxygen is used to oxidize the carbon and hydrogen in the acetylene. This gives a more intense flame than if air were used, because more oxygen can be used in a given time and because the nitrogen in the air (about four fifths of the air) does not have to be heated up by the flame.

To make this a little clearer, suppose we had a flame through which was passing a gas that had been cooled to a temperature below zero. It is evident that in passing through the flame, this gas would be heated and so take heat away from the flame. If there were enough of a sufficiently cold gas, it is clear that the flame temperature would be so reduced that the flame would go out. Water puts a flame out by this reduction of the temperature. Now the air is only one-fifth oxygen, while the rest is nearly all nitrogen, another gas, which has no effect on combustion, but which, in passing through the flame, must be heated and so take away some of the heat from the flame.

Flame Temperature; Total Heat

We must now look at the difference between flame *temperature* and the *total heat* produced by burning any fuel. Temperature does not depend at all on the *amount* of fuel burned. A gas jet, burning 5 hours would burn 5 times as much gas, (or fuel) as if it burned one hour, but the *temperature* would be the same in both cases. In other words, *temperature* is what is used to measure the *intensity* of a flame. The *total heat*, or *quantity* of heat secured from the fuel, depends on how much of it is burnt and if more of it is burnt by any means in a given time in the same space, the resulting temperature must be greater.

The amount of heat given off by the complete burning of one pound of any fuel, is measured by a Heat Unit, just as a length is measured by a unit called an inch. Six inches means a length equal to six units of an inch length each.

A Heat Unit is the amount of heat needed to raise the temperature of one pound of water, one degree (F), as measured by the thermometer. Five hundred Heat Units would raise the temperature of 500 lbs. of water, one degree, 250 lbs., two degrees, or 100 lbs., 5 degrees. So if a pound of fuel gives off enough heat to raise the temperature of 8000 pounds of water one degree, if it were all absorbed by the water, we say that the heat of combustion, (or heat made by the burning), of the fuel is 8000 Heat Units, it being understood that this is the heat from one pound of fuel.

We have now two ideas before us:

1st, that the temperature of a burning fuel is its intensity as measured by a thermometer and that this temperature does not

depend on the amount of fuel burnt, but on the conditions under which it is burnt.

2nd, that a pound of fuel will give off a definite and fixed amount of heat when it is burnt, no matter what the conditions of burning, provided only and always that it is completely burned.

This makes it clear that the total heat in any fuel is no measure of the flame temperature that may be produced in burning it and that the flame temperature of a fuel has nothing to do with the total amount of heat produced by burning it. This should be clear in the welder's mind, so that he will not be confused by a common argument, that because a welding gas has more total heat in it than acetylene, that its flame temperature is higher. Acetylene when burnt in the presence of pure oxygen gives the highest known flame temperature and is therefore the best gas for welding.

For cutting, other gases may do just as well, or in some cases better and may be cheaper, as for instance where electrolytic oxygen is made in the shop and hydrogen is wasted unless it is used for cutting, in which case the use of hydrogen is economical. There are other gases that are used for cutting, such as Calorene, Blaugas, Pyrogen etc. and which are very successful in this work, but which cannot compete, either in speed or ability of work, with acetylene for welding.

The temperature of any flame is very difficult to measure and it is not thought wise to discuss the matter here. But it may be said that the flame of an ordinary candle is hot enough to melt a platinum wire, if the wire is fine enough. A heavier wire conducts the heat away so fast that it cannot be melted. Any flame temperature may be calculated theoretically, however, if the composition of the fuel and the conditions of the burning be known. * The theoretical flame temperature of acetylene burned by pure oxygen is 7250°F and making allowance for heat lost by radiation and other causes, is probably in actual practice about 5500°F. †

Welding of Cast Iron

It is evident that the temperature of the oxyacetylene flame is high enough to melt cast iron, which has a melting point varying from 2000° to 2200°F depending on its composition. But here again we must remember that, while cast iron is not a very good conductor of heat when compared with some other metals, yet it does conduct heat rather quickly. So if we want to melt it, we must put heat into it faster than the cast iron will carry it away to the air or other cool objects near it. In other words, we could not melt a cold block of iron a foot thick with a number two tip.

Preheating Costs

It should also be remembered that while the *temperature* of the oxy-acetylene (o.a.) flame is very high, the total *quantity* of heat delivered in a given time is comparatively small. The total heat

*Any one interested can find the details in Metallurgical Calculations, by Jos. W. Richards.
†Private communication from Jos. W. Richards to S. W. Miller

given off by the burning of one pound of acetylene (say 14½ cu. ft.) is equal to that given off by the burning of about 1.4 lbs. of charcoal. A No. 5 DB or No. 7 Oxweld tip burns about the above amount of acetylene per hour. So it is clear that the use of the oxy-acetylene flame for preheating is much more expensive than any of the usual methods, such as charcoal or city gas and even for small work it is well to use some cheap method of preheating whenever it is possible.

Fusion

But on the other hand, the intense heat of the o.a. flame is concentrated into a very small space, so that the temperature of a small spot is raised by it rapidly. This quality is what gives the o.a. flame its value in welding, because its heat is poured in very fast and except in unusual circumstances, faster than it can get away, so that the metal is finally fused. This fusion is the essence of o.a. welding and the lack of fusion is the cause of all real difficulties in welding. It will not do to rub a melted welding rod over a red hot surface of the base metal, as no real joint will be obtained. The real weld is only made when the added metal and base metal, both melted, run together of themselves.

Cast iron is the easiest metal to weld, because:

1st, it does not conduct the heat away rapidly.

2nd, because of its melting point.

It is difficult to weld in complicated sections, because,

1st, it is brittle at all temperatures.

2nd, it is weak at all temperatures.

Expansion and Contraction

It is frequently difficult to make clear to a young welder or student, what happens when a piece of metal is heated. The statement is made that heat expands and cold contracts, any metal But a simple experiment will make it easy to see what really occurs. Put a piece of steel rod about 12″ long and say ½″ diameter, between two heavy blocks of iron, or steel, so that they just touch the ends of the rod, heat the rod with a torch till it is red hot and let it cool. It will be found that the blocks have moved, as the rod is no longer touching them and measuring the rod before heating and after cooling shows that its length has not changed.

Therefore, every time a piece of metal is heated, it gets longer and when it cools it comes back to its original length. * Also the greater the heat, the longer it gets. *

Further, the lengthening must create some force, or the blocks would not move. This force is really very great and if the blocks are held so they cannot move, the force is used up in shortening the bar, as measuring it after cooling will show.

It should now be clear that irregular heating of a cast iron piece, which is by nature, brittle and weak, may create forces or strains

*While these statements are generally true there are exceptions to them. They are correct enough for the present purpose.

in a part of it, which would cause cracks and that even if the weld be sound, the cooling of an unevenly heated piece may result in the same trouble.

To avoid this uneven heating and cooling is the most difficult part of cast iron welding. It seems that while a welder may see clearly that heat expands metals and that strains result from irregular cooling, the difficulty lies in applying this knowledge to specific cases as they come to him.

Another easy experiment may help to make our ideas clearer. If we take a flat sheet of 1-16 in. steel 12 in. square and heat it in the center in any way, say with a welding torch and allow it to cool, it will warp out of shape and no amount of clamping will stop the warping. The reason is that the hot spot tries to expand or get larger and the cold metal outside will not let it. So either the hot part must upset, getting thicker in places, or it must twist and bend to relieve the strain. During the heating, the rest of the plate changes but little, if any, in shape, but on cooling the twisted and upset hot spot shrinks, or gets smaller and the resulting strains buckle and twist the whole of the plate, because the plate is solid and the strains are transmitted through all of it, though they may not be of the same amount in all directions.

Preheating

Now, if the sheet had been preheated all over to a red heat before heating it in the center, it would have done much of its expanding before the torch flame touched it and so it would cool more uniformly than before. But still there would be some difference in temperature between the center and the rest of the plate and so some twisting or warping would occur.

The only way to get uniform shrinkage in the sheet would be to have it at the same temperature all over as the weld is and this means melting the whole sheet, which is not possible.

Now suppose that the sheet *was* heated up to a uniform temperature in a furnace, but that part of it was dipped in water and the rest allowed to cool in the air. This would again cause strains because part of the sheet would be cooler than the rest of it and the soft, hot part in shrinking as it cooled, could not move the stiff part.

This last illustration is quite appliable to cast iron welding in cases where part of the weld cools off rapidly, as in a thin piece where the weld is of some length. It also applies where the weld is made in only part of a piece, as in filling up hole in a heavy casting. If this be done without preheating, it is the same as heating the sheet and cooling part of it rapidly.

Even in pieces of cast iron that are only about 1″ thick and 4″ wide, the difference in temperature between the two ends of the weld may put enough strain into the piece to cause it to crack

when put into service. All such welds may properly be called "restrained" welds, because the weld is prevented from contracting freely. In restrained welds, it is not possible to avoid both strain and warping. The warping, or distortion, may be got rid of in the steel sheet by hammering it on a block, but this leaves hammer strains in the sheet. It could not be done with cast iron.

It is clear that preheating such pieces is absolutely necessary for successful welding and that after welding they should be reheated to a uniform temperature all over, so that they may be cooled uniformly and in doubtful cases this should be done rather than run the risk of cracking.

It is recommended that the welder, especially the student, try the above simple experiments himself, because if the effect of heat is thoroughly understood and a little thought given to each new case as it comes up, there will be little difficulty in getting good results.

Summary

The points brought out may be summarized as follows:

1. Acetylene is the best gas for welding, because of its high flame temperature.
2. Flame temperature has no relation to the total heat given out by burning gas.
3. The temperature of the o.a. flame is higher than that of any other flame, but the quantity of heat given out is not greater than some other fuels.
4. The o.a. flame, in its practical application, is very small and therefore the heat is applied in a small spot, rapidly raising it to the fusing point. This is of advantage during welding, but may be a disadvantage by causing local strains at the melted part during cooling.
5. These strains are especially dangerous in cast iron, which is weak and brittle, unless the part be reheated after welding to a uniform temperature all over, when the strains will be relieved, because cast iron will stretch a little when hot. Covering the piece with anything that will slow the cooling down will help, because the strains will have more time to adjust themselves.
6. Preheating is necessary in all complicated cast iron pieces, to avoid irregular heating during the welding as much as possible and the hotter the piece is heated, the better, because the less the difference in temperature between the weld and the other parts of the piece, the less strain. The average temperature of a casting as brought to the welder is about 70°F. The melting temperature of cast iron is about 2100°F, a difference of about 2030°F. If the piece be preheated to only a dull red, its temperature will be about 1300°F, a difference of only 800°, which accounts for the good results from preheating.
7. The use of the o. a. flame for preheating is expensive, even

for small work, and for the sake of economy, other cheaper methods should be used. Also, preheating reduces the cost of welding by reducing the amount of oxygen and acetylene used.

8. The greatest difficulty in cast iron welding is to take care of the strains which occur during preheating, welding, and cooling. Slow preheating, rapid welding, reheating after welding, followed by slow cooling, are the means to be used, especially in restrained welds.

9. In such welds, either strains or distortion can be prevented, at least for all practical purposes, but it is not possible to avoid both. Strains, being dangerous, should always be avoided, even if some distortion is necessary.

Preparation Before Welding

It is necessary for successful work, to prepare or design the pieces so they can be easily, quickly, and thoroughly welded. The angle of the V is very important in this connection. It is usually made with an included angle of 90°degrees* and this is generally correct, though there are exceptions to the rule. If the V be too narrow, it is not possible to fuse the bottom, because the metal from the sides will cover it over before fusion can occur. So if the V angle be great enough to get thorough fusion at the bottom, that is enough, and any greater angle is wasteful, needing more time and gases to fill it up.

In vertical welding, especially where the section is heavy, it is seldom necessary to use an angle of over 70 degrees, and less is simetimes enough, because the heat is confined more than in horizontal work, and fusion takes place more easily.

As stated before, the rule is to make the V no wider than needed to get thorough fusion at the bottom, but one must be sure to get this fusion. It should also be remembered that with too narrow a V, it is possible in some cases to melt it wide enough, yet this is expensive. It is much easier and cheaper to make the V of the right width in the first place.

With pieces that are thin, or that have to be lined up by the break, it is sometimes better not to V them, but to set them together in their proper places, and burn out the V with the torch. But these cases are few, and this method should be used but seldom.

The size of tip is not so important with cast iron as with some other metals, as overheating of the metal can hardly be caused by any size tip that can be used without having the metal run away. Too much heat will burn out enough of the carbon and silicon to tend to make the weld hard, but usually before this occurs, the welder finds it impossible to keep the melted metal in place, and changes to a smaller tip. In any case the tip is of the right size if the metal is easily and thoroughly fused, without control of

*An angle of 90 degrees is that made by the legs of a carpenter's or machinest's square, so that if the corner of one of these tools be set in the V, it should fit.

it being lost, and so an expert welder can use a larger tip than can one with less experience.

Welding Wire

In all cases some of the valuable elements in cast iron are lost during welding, such as carbon, slicon and manganese. If these can be replaced, the cast iron will not be injured. This can be done at least partly by making the welding rods of proper composition.

Of course a welder gets all kinds of cast iron to work on. But an average grade of good machine iron is usually what comes to him. In the table are given the composition of such an iron, and that of welding rods as called for by the A. W. S. folio No. 1-G.

	Machine iron	Welding rods
Carbon	3.50%	3.00 to 3.50%
Manganese	.75%	.50 to .75%
Phosphorus	60%	.50 to .70%
Sulphur	.09%	.10%
Silicon	2.00%	3.00 to 3.50%

There is clearly no essential difference between them, except in the silicon, which is high in the welding rod.

Hardness in Welds

Now hard welds are not wanted, especially if they have to be machined and as there is no need of having them, it will be well to give a short explanation of how to avoid them.

Let the welder again make, a few simple experiments. First make a little button about ¾" diameter and ¼" thick, by melting down a piece of good welding rod on a heavy piece of iron, without welding it to the iron. Make another one, but use any ordinary cast iron in place of the welding rod, and let them cool just as they stand. Make another one from the welding rod, and as soon as it is made, while still red hot, throw it into cold water. The last one will be found so hard that it cannot be filed or machined. Of the others, the one made from the welding rod will be found quite soft, while the second one, made from ordinary cast iron, will be harder, and may be very hard on the bottom.

Again, heat the corner of a rather heavy piece of cast iron to a red heat with a small tip, not melting it, and let it cool. The heated part will be found file hard.

Now all these tests involve the rate of cooling of the heated metal. The same metals are cooled at different rates, and different metals at the same rate. All that are quickly cooled are hard, and the slowly cooled ones are soft. Even the welding rod, which is usually soft after welding, can be made hard by rapid cooling, while ordinary cast iron if cooled slowly enough, as in a casting, is always soft.

This is the explanation of hard spots in cast iron welds. The

remedy is clear and easy; do not allow any part of the weld or metal around it to cool too rapidly. The method to be used in any case depends on the case. But preheating, reheating and slow cooling, as before explained, will stop the trouble. Remember, however, that small castings cool rapidly and that it is in these that hard spots usually occur, which means that they must be handled more quickly and carefully than heavy casting which holds its heat for a long time. The conclusion is that, as hard spots in ordinary cast iron can be avoided, it is the fault of the welder if they exist.

As before explained, silicon, in sufficient quantity, keeps cast iron soft, even with rather rapid cooling, so, as many small welds are cooled fairly quickly, it is necessary to have more silicon in the welding rod than in castings, as is shown by the given compositions and no welding rod should be used that has less than about 3% silicon. This is so well recognized by the makers, that practically all rods on the market will give good results.

Quality of Welds; Use of Flux

A cast iron weld properly made will always be stronger and fine grained than a casting made in a foundry. It will also be somewhat harder, but will never give trouble in machining. The more rapid cooling of the weld metal prevents the carbon separating out as graphite, which would make the weld softer. So there is but little use in discussing the strength of cast iron welds, it being enough to say that they should always be stronger than the cast iron in which they are made and that their exact strength is therefore of no interest.

One defect in cast iron welds which can always be avoided, is porosity. A welder will notice that sometimes a blowhole will persist, even when the metal is remelted several times. But if he will melt down far enough, he will find at the bottom of the hole a small white speck, which is probably sand and if he melts under this and allows it to float to the surface, the blowhole will disappear.

This trouble is annoying, especially in such cases as rebuilding valve seats in a gas engine cylinder and it is good practice to go all over them a second time, to be sure that blowholes are absent. No flux should be used in the second melting.

The use of a flux is necessary when welding cast iron, but it cannot take the place of the heat from the torch. That it, the torch does the melting and not the flux. Some welders seem to think that by throwing large quantities of a flux into a weld, it makes welding easier and the weld better. This is a wrong idea and tends to result in poor work. A flux, which means something that makes the metal flow easily, is for the purpose of cleaning the surface of the melted metal from the scale which forms on it and is therefore sometimes called scaling powder.

Any melted metal is attacked by the oxygen in the air and becomes covered with a coating of oxides of the element in the metal. These oxides, in the case of cast iron, have a higher melting point than the cast iron and so stay on the surface as a thick scum, which may interfere occasionally with the welding. When this occurs, a little flux on the rod or a small amount dropped into the weld where it is needed, will combine with the oxides and clean the surface, as is known to all welders. A few tests will show that only a little is needed. Further, it is a disadvantage to keep the melted surface too clean, and as this is an important matter, it will be discussed at some length.

A melted metal not only oxidizes readily on the surface, but absorbs gases freely. Just as soon as the surface is cleaned, it begins to coat over again, because fresh surfaces are exposed to the air and this fresh surface is what absorbs the gases. If the scum be there, it is difficult for the gases to be absorbed, or for the metal to oxidize any more. So the scum should be kept in place unless it is absolutely necessary to remove it. The end of the welding rod should stay in the melted pool and the torch flame be kept on it and the pool, moving them around together to where the metal is needed. The rod and base metal will be melted under the coating and run together without rubbing. When the coating gets too thick, just a little flux will remove it enough to start over again.

This method will also prevent to a large extent the burning out of good elements in the cast iron, such as carbon and silicon, which will keep the weld softer and tougher. It is also faster, as metal is being continually added.

As with all rules, there are a few exceptions to this one. If a a sand hole be met with, it will be necessary to melt around the sand and pull the dirt out with the rod. With burnt cast iron, such as grate bars, or furnace parts, it is necessary to rub the rod gently along the surface of the base metal. Rubbing hard, simply removes the metal and exposes a fresh surface, so that nothing is gained. The use of pure borax as a flux in such a case is sometimes helpful, but is not necessary for ordinary work.

The conclusions are:

1st, that no more flux than is absolutely necessary should be used.

2nd, that the rod should be melted under the surface coating of oxides, or slag.

3rd, that rubbing the rod around in the weld continually is bad practice, as it stirs up the metal and exposes fresh surfaces to the air, which means more slag, that may be included in the weld and make it weak.

Welding White and Malleable Cast Iron

The welding of chilled or white case iron is no different from

that of grey cast iron, except that if the welds are to remain hard, chilled iron welding rods must be used. Because of its brittleness, it is necessary to be very careful to preheat thoroughly and cool slowly.

Malleable cast iron, usually called malleable iron, cannot be melted without changing it back to the chilled or white iron from which it was made, so that it is customary to bring it only to a good red heat and use tobin or manganese bronze welding rods. The result is excellent, as these rods have in the weld very great strength and ductility and it is very rare to have any breakage of such a "weld", if proper rods are used.

Care must be taken not to keep the welding flame on the bronze any longer than necessary, as its strength is thereby reduced, or even destroyed. Any good brass flux may be used, but sparingly.

The proper way to weld malleable iron is to bring the surfaces to a dull red heat, apply a little flux from the end of the rod, melt it on the surface and then put a drop of bronze on the fluxed surface. As the heating is continued, there will come a time when the bronze will suddenly spread over the surface. It is not necessary to heat any higher than this and in fact it is bad, because when too hot the bronze does not unite freely with the iron.

After the iron is coated, the necessary amount of bronze is easily added, as its melting point is low and as it flows very freely. There is some tendency to blowholes, with some bronze rods, but good ones give little trouble. The use of more than a very little flux will cause blowholes and the metal should be added under the surface coating, as with cast iron.

Conclusions

Finally, it may be said that with thorough fusion, proper allowance for expansion and contraction, adequate preheating, slow cooling, the use of proper welding rods and no more flux than necessary, the welding of cast iron is uniformly a success and that the weld is always stronger than the base metal and readily machineable.

PRESENT STATE OF THE ART OF RESISTANCE WELDING

There is given below the second of a series of papers that are being prepared under the auspices of the Resistance Welding Committee of the American Bureau of Welding to set forth the present state of the art and knowledge of Resistance Welding. This Summary will serve the two-fold purpose of giving the industry a consise statement of the best existing information and enabling the Committee to draw up a careful program of needed research. Discussion which will bring out additional information is particularly invited.

Respectfully submitted,
H. Lemp, Chairman, Resistance Welding Committee
C. W. Bates,
E. F. Collins
J. E Chamberlin
A. F deForest
A. E. Hackett
O. S Hammack
E. J. Henke
H L. McCreery
D. F. Miner
Jos. A. Osborne
W. Remington
W. H Tobey
M. Thomson

---

*BUTT WELDING

SLOW BUTT METHOD

I. Welding of Two Pieces of Same Material and Cross Section.

(A) Ferrous Metals:

(1) *Solid Cross-Sections.*—(rounds, squares, parallelograms where difference between altitude and length of base is not too great.)

Parts to be welded are clamped in dies of welding machine, giving equal projections to both parts, the ends of which are then brought together, current applied, the joint allowed to reach a welding heat, when rapid and heavy pressure is applied, forcing the ends together and completing weld. At the same instant that pressure is applied, the current supply is stopped. The proper projection of parts will vary from a length somewhat greater than their diameter of thickness in small sections to a length somewhat less in large sections. On all round, equilateral, or nearly equilateral sections, having considerable areas, parts should have at least two diametrically opposite, or nearly diametrically opposite, lines of contact, with current carrying dies to insure even heating over entire cross-sectional area. In case the abutting ends do not heat evenly, due to highly localized points of contact between their faces, this can be corrected by what is known as "nursing," that is, the stopping of current supply for a short period to allow the heat to

*Prepared largely by Mr. W. Remington, Chief Engineer, Thomson Electric Welding Co.

distribute itself, when current is again applied and heating continued. Several applications of this "nursing" may sometimes be necessary.

(2) *Tubes.*—The slow butt method of welding tubes is generally used in making refrigerator coils and where the actual weld is to be completed by rolling between mandrel and rolls as is being done by some in the safe ending of boiler tubes. Welds of this character have no burr or projection on the inside of the tube. The general rule for clamping, heating etc., is the same as in the welding of solid sections, except that the projection used is somewhat greater than would be used were it a solid section of same cross-sectional area. Also the amount of metal pushed up during final application of pressure is less than on solid sections, for, as stated above, the weld is completed by immediately placing tube upon a mandrel and rolling down this pushed-up metal, or upset, until its diameter is the same as that of the tube. On pipes or tubes, 2 in or under in diameter, three lines of contact (with currant carrying dies) approximately 120° apart is sufficient, but on all tubes over 2 in. in diameter, the dies should make contact over nearly the entire periphery, to insure even distribution of heat.

(3) *Irregular Shapes.*—Irregular shapes, such as angles, tees, channels etc., are seldom welded by the slow butt method; rather, the flash method is used, which is described later.

(B) Non-ferrous Metal:

(1) *Solid Sections.*—(excepting thin flat strips) Due to the fact that the period of plasticity on the temperature scale of copper, brass, aluminum, lead and zinc, is so short, the hand operated pressure butt welder is not so well adapted to the making of a slow butt weld as a welder having spring or weight pressure, the full amount of which is exerted throughout the entire heating and welding operation. The parts to be welded are clamped in dies, so as to give a projection about three times that used in welding a piece of steel of same cross-section, the full pressure to be used applied and the primary circuit closed. As soon as the abutting ends reach the welding or plastic stage, this spring or weight pressure forces them together, completing the weld, at the same time automatically breaking primary circuit. The above method is rarely used on parts having over 0.25 equare inches, cross-sectional area, as the general use of this method is for the splicing of ends of coils of copper wire for winding purposes and the sizes rarely exceed this area. Due to the fact that the metal at the weld is softer than the original drawn wire, its strength cannot be as great. The welding of large sections (four or five square inches) of copper has never been successfully accomplished, perhaps because the absence of any demand for same has not stimulated its development. Brass, however, gives better results than copper and

quite strong welds can be obtained, but by the flash rather than the slow butt method. German silver also lends itself more readily to the flash method. Comparatively little has been done in the welding of aluminum, lead and zinc, but where no great strength is desired, they can be welded by the above slow butt method.

(2) *Tubes.*—The welding of tubes of copper, brass or aluminum has never been a success commercially, for while it is possible to make a weld that will not "leak", its strength is small. All welds are made by the flash method, the slow butt method seldom, if ever, being employed.

(3) *Thin Flat Strips.*—Here again the flash rather than the slow butt method is preferred and here again brass is the only one of the more common non-ferrous metals on which it is possible to obtain a weld having any great strength.

II. Welding of Two Pieces of Same Material but Different Cross Section.

(A) Ferrous Metals:

(1) *Solid Cross-Sections.*—(rounds, squares, parallelograms where difference between altitude and length of base is not too great).

The general welding procedure is the same as used in *Welding of two pieces of same material and cross-section,* excepting that the tendency of the piece having the smaller cross-sectional area to heat the faster, is offset in one or more ways, as follows:

(a) By varying projection of parts, that is, by making the projection of part having larger sectional area somewhat longer than that of the smaller. This aids the distribution of heat in parts in one or more ways: First, by virtue of the fact the copper dies gripping the parts are good conductors of heat and therefore, making the projection on part which would normally heat the slower, of such a length that this loss of heat by conductance is reduced to a minimum, while increasing this loss in the smaller part by giving in a short projection even heating of ends may be obtained. Also, this varying of projections tends to equalize their electrical resistance. This equalizing of heating of parts by varying projections only, is employed only where the difference in cross sectional area is slight.

(b) By preheating larger section. When the difference in cross-sectional area is of any great amount, the tendency toward uneven heating is offset by preheating the end of part having the greater cross-sectional area. This may be done in the welder by means of what is known as a "bridge", which is a channel-shaped piece of copper, the two legs of which span the projecting end of smaller part and make contact only with copper dies gripping this part, while the outer or back face of channel makes contact with end of larger part; thus when the circuit is closed, the current flows through and heats this larger part only. When this larger part has reached a fairly high temperature, the "bridge" is re-

moved the end of smaller part brought in contact with end of larger and weld completed in usual manner.

(c) By combining above two methods.

(d) Perhaps one of the most common methods employed in the welding of two pieces, having different cross-sectional area, is to turn down the projecting end of larger to give it the same area as that of smaller. It then becomes a weld of the first type.

(2.) *Tubes, irregular sections, thin flat strips.*—The welding of the above is seldom encountered, but the method followed would be the same as described under various subdivisions of (1) (Solid Cross Sections).

(B) Non-ferrous Metal:

The general welding procedure is the same as in *the Welding of Two Pieces of Same Material and Cross-Section,* excepting that the tendency of the piece having the smaller cross-section to heat the faster, is offset in one or more ways as follows:

(a) By varying projection of parts, as described in (a) under Ferrous Metals.

(b) By turning down projecting end of larger part, as described in (d) under Ferrous Metals.

(c) By combining above two methods.

III. Welding of Two Pieces of Same Cross Section but Different Material.

(A) Various Analyses of Ferrous Metals, one to Another:

(1) *Solid Cross Sections.*—(round, squares, parallelograms where difference between altitude and length of base is not too great).

The general welding procedure is the same as in *the Welding of Two Pieces of the Same Material and Cross-Section* excepting that the tendency of one piece to heat faster than the other is offset in one or more ways as follows:

(a) By varying projection of parts, that is, by increasing the projection of part which would normally heat the slower, as described in (a) under *Welding of Two Pieces of Same Material, but Different Cross-Section.* This difference in projections will vary from very little where parts have similar thermal and electrical characteristics to a point where the ratio in length of projections is as 1 to 4, as in the welding of high speed steel to wrought iron, where no preheating is done.

(b) By preheating slower heating part, with bridge as described in (b) under *Welding of Two Pieces of Same Material, but Different Cross-Section.*

(c) By combination of above two methods. This latter is the more practical and universally used method.

(B) Various Analyzes of Non-Ferrous Metals One to Another

The welding of non-ferrous metals, one to another, is rarely done

by the slow butt method, rather the flash method is used.

(C) Non-ferrous Metals to Ferrous Metals

Here again the flash rather than the slow butt method is used, excepting in the welding of very small parts, such as platinum wire tips onto spark plug stems, where an automatic welder, similar in action to the machine described above for welding of copper wire, etc., is used.

IV. Welding of Two Pieces of Diferent Cross Section and Material.

(A) Various Analyses of Ferrous Metals, one to Another:

As described in (A) under *Welding of Two Pieces of Same Cross-Section, but Different Material.*

(B) Various Analyses of Non-Ferrous Metals One to Another

Here again the flash rather than the slow butt method is used.

(C) Non-ferrous Metals to Ferrous Metals

Here also the flash rather than the slow butt method is used.

FLASH METHOD

I. Flash Welding of Two Pieces of Same Material and Cross Section.

(A) Ferrous Metals:

(1) *Solid Sections, Tubes, Irregular Shapes.*—Parts to be welded are clamped in dies of welding machine giving equal or nearly equal projections to both parts, the primary circuit closed and the ends of parts brought together slowly. When these ends actually touch each other, they will "flash", that is, minute particles of molten metal will fly off; this flashing is continued until the entire faces of abutting ends have reached a welding heat when rapid and heavy pressure is applied, forcing ends together and completing weld, at the same time opening primary circuit. The above is, without doubt, the preferred method of welding, as the power and time consumption is considerably less and the personal equation of the operator enters to a much less degree than in any other type of weld, thus producing more uniform results. At the present time, some difficulty is encountered in flashing parts having cross-sectional areas of over 8 to 10 square inches, where the ratio of their cross-sectional dimensions is over 50 to 1, or less than 4 to 1, although by preheating parts in latter case, this difficulty is greatly minimized. There are two types of flash welds, the "cold flash" and the "preheated flash".

a) *Cold Flash.*—By cold flash is meant that the parts to be

welded are not preheated in any way. This cold flash is used where parts are of an area well within limits of designed capacity of welding machine.

(b) *Preheated Flash.*—By preheated flash it is meant that the parts to be welded are brought together in contact with each other before current is applied, as in the slow butt weld, the abutting ends allowed to reach a more or less high temperature, when the circuit is broken, the parts separated, the circuit again closed and completed as a flash weld of the first type. The preheated flash is used in welding parts having condensed sections of an area closely approaching the design capacity of welding machine and also where the physical or thermal characteristics of parts are widely divergent, as will be noted in several cases below.

(B) Non-ferrous Metals:

In welding of non ferrous metals the cold flash is used entirely and is described under (A). The projection of parts should be two or three times as great as in the welding of low carbon steel.

II. Welding of Two Pieces of Same Material but Different Cross Section.

(A) Ferrous Metals:

The general welding procedure is the same as in the *Flash Welding of Two Pieces of Same Material and Cross-Section* excepting that the tendency of the part having the greater cross-sectional area to heat more slowly is offset in one or more of the following ways:

a) By varying projection, that is, by increasing projection of part having larger sectional area over that of the smaller for the same effects as given under *Welding of Two Pieces of Same Material, but Different Cross-Section* by the slow butt method. The varying of projections only is used where the difference in sectional area is slight.

(b) By preheating larger section. As described under Slow Butt Method.

(c) By varying the amount flashed off, that is, by flashing off an amount greater than would be, were the parts of the same area. This gives the heat a chance to equalize itself in the two parts.

(d) By combinations of above.

(B) Non-ferrous Metal:

As under (A) excepting that no preheating is used. The welding of parts having large sectional areas to parts having small areas, can be done only by preparing them such that the projection of the larger has approximately the same area as that of the smaller.

III. Flash Welding of Two Pieces of Same Cross Section but Different Materials.

(A) Various Analyses of Ferrous Metals, one to Another:

The general welding procedure is the same as in *Flash Welding of Two Pieces of the Same Material and Cross-Section* excepting that the tendency of one part to heat faster than the other is offset in one or more ways as follows:

(a) By varying projection, that is, by increasing the projection of the slower heating part over that of the other, where normal unit difference in heating time is slight.

(b) By preheating slower heating metal. As described under slow butt method.

(c) By varying amount flashed off. As described in (c) under *Flash Welding of Two Pieces of Same Material, but Different Cross-Section.*

(d) Combinations of above.

(B) Various Analyses of Non-Ferrous Metals One to Another

As under (A) excepting that no preheating is used. Welds between copper and various analyses of bronze or brass have been obtained, which had tensile strengths very nearly as great as that of copper wire, annealed. Large sections (four and five inches) of non-ferrous metals have never been welded.

(C) Non-ferrous Metals to Ferrous Metals

As under (A) excepting that no preheating is used. Welds between C. R. Steel and brass, bronze or copper have been obtained which had tensile strengths very nearly as great as that of the metal to which the steel was welded. The welding of stellite to ferrous metals is described under separate heading.

IV. Flash Welding of Two Pieces of Different Cross Section and Material.

The above is really a combination of the conditions met in the *Flash Welding of Two Pieces of Same Material, but Different Cross-Section* and the *Flash Welding of Two Pieces of Same Cross-Section, But Different Material* and would be welded by one or more of the following methods, all of which have been described above.

(A) Ferrous Metals One to Another

(a) By varying the projections.
(b) By preheating slower heating metal.
(c) By combinations of above.

(B) Non-Ferrous Metals One to Another

(a) By varying projections.
(b) By varying amount flashed off.

(c) By combination of above.

(C) Non-Ferrous Metals to Ferrous Metals

As in (B).

In all above cases where the difference in cross-sectional areas is of any amount, say more than one and one-half or two to one, it is much better practice to prepare parts for welding by reducing the area and shape of the larger part to that of the smaller, thus making it a flash weld of the first type.

V. Welding of Stellite to Ferrous Metals.

The welding of stellite can be satisfactorily accomplished only by the preheated flash method. This preheating may be done in one of the following two ways: The parts are clamped in dies so as to give a projection of steel from 6 to 8 times that of the stellite piece, the ends then brought together and mutually preheated by rapidly bringing them into contact with each other and then separating again, with welder circuit closed. This is continued until required portions of projections have reached a fairly bright heat, when the weld is then made as in an ordinary flash weld. The other method of preheating is to use a bridge (previously described) and preheat the steel part only. If this latter method, which is the better method, is used, the difference in projections of parts need not be as great as in the first method, in fact, this difference is of small importance.

VI. Angle Welding.

By this is meant the welding of parts at any angle less than 180°, such as rectangular frames of angle iron, flat strip, various shapes of tubing, etc. The general cold flash method is used.

VII. Tee Welding.

As the name implies, this is the welding of two parts at right angles to each other. Either the slow butt or the flash method may be used. In either case the head of tee should be preheated, either by bridge, or where parts are small or are to be flash welded, they may be mutually preheated by "nursing". Where the top of the tee is of a cross-section larger than the vertical part of the tee, it is sometimes necessary to use a welder so designed that the current at first flows only through the top of the tee, thus heating this piece. The current is then changed to flow from the vertical part of the tee into the previously heated top of the tee, bringing both pieces to a welding temperature and the weld is completed by the usual push-up.

PART FLASH PART SLOW BUTT METHOD

This is when the weld is started as a cold flash and finished as a slow butt weld, as is particularly applicable to the welding of

such parts as tubing, where the weld is to be completed by rolling between mandrel and rolls, as here the flash must be kept at a minimum, also in welding of hollow rock drill steels, where any great amount of flash would cause the hole to become clogged. By starting as a flash weld, the inequalities of the surfaces of ends of parts are burned off, so that when they are brought together for final heating preparatory to upsetting, the ends make good contact over entire area and thus insure even distribution of heat.

SUPPLEMENT

As a supplement to the foregoing, I would say that the successful completion of many welds is only brought about through specially designed dies or through specially forming the pieces to be welded. Dies may be cut out or relieved in certain places so as not to conduct the heat away from the welded part so rapidly as would otherwise have been the case, Also the cooling effect of the dies is many times utilized to prevent the heat running back too far or to prevent the overheating of the piece in a certain locality. This matter of properly fitting the dies is of much greater importance where the slow push-up method of welding is used than it is where the flash method of welding can be used, due to the fact that when the flash method of welding is used, the resistance of the arc is so great that the current distributes itself very evenly and also due to the fact that most of the heating effect is due to the heat of the arc instead of due to the resistance of the metal to the current flowing through it.

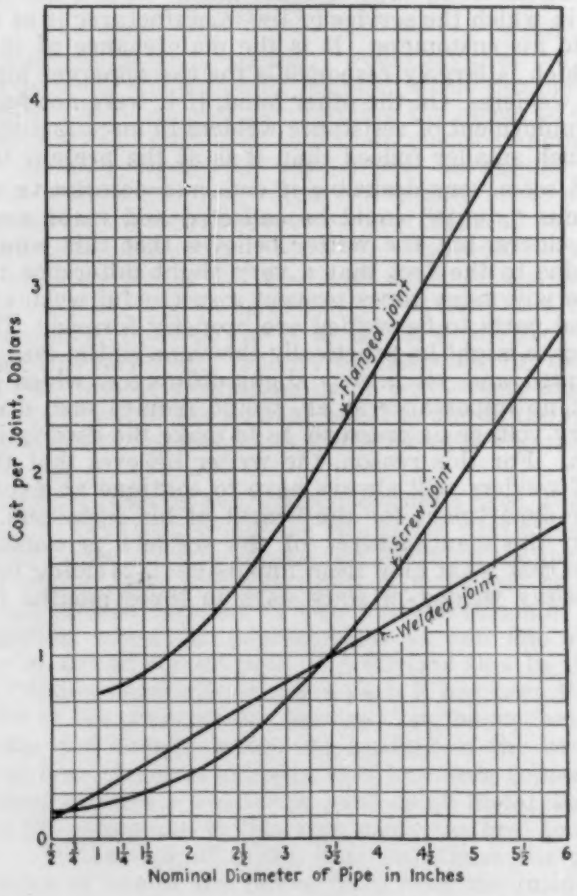
When the slow push-up method of welding is used, the heat will always start at the point where the two pieces first come together. This is many times a disadvantage and slows up the process, such as you can well imagine would be the fact in the case of two pieces of pipe being welded together or two round sections of rod being welded together where the contact came on one side and on the outer edge of either bar or pipe. To obviate this in the case of bars, many times, especially in years past, it has been the practice to point one or the other of the bars so that the contact will start at the center and thereby cause the heating of the bars to start from the center. Another practice that has been followed in this case has been to place a washer or solid small metal disc between the ends of the pieces and in this way, cause the heat to start from the center. In the case of pipes, it is sometimes the practice to bevel the edge of one of the pieces from both the inside and outside so as to cause the start of the heat at the center of the wall of the pipe. In the case of wires or bars, which have been sheared off, it has been the custom to place them in the dies so that the ridges left by the shears cross each other at right angles, and thereby cause the heating to start from the center. Later practice, however, has been to flash the parts for a second or two and thereby even up the surfaces before the parts are brought together and heated for the completed weld.

There are many "tricks" or "stunts" used when welding two pieces of different form together, such as where a flat piece is welded into the end of a round pipe or a knife blade into the handle of a knife, or in the case of where two flat rectangular pieces are welded together with their longest cross-section dimension at right angles to each other. As these "tricks" or "stunts", however, are very great in number and as they apply generally to the individual case in question and cannot be applied generally, I believe that it would be useless to try to enumerate them. This is really the part of the art in which the service of the manufacturer is of the greatest value to his customers. It is the maintenance of this sort of service, which is largely responsible for the apparent high cost of resistance welders. On the other hand, if it were not for this service, the employment of resistance welders in manufacturing would be very much smaller indeed than it is at the present time.

It would seem very desirable if cuts and descriptive matter of these various "stunts" could be collected and made available to users of welders, but the writer believes that this would not be practical, due to the fact that a very slight difference in voltage or pressure will many times prevent a successful weld, even when the dies and parts to be welded are properly formed. The manufacturer's case might be practically the same as the case described and illustrated and yet a very slight difference, which he might consider of no importance at all, would require such a difference in secondary voltage or pressure, as to make the description valueless to him. For this reason, the writer believes that the manufacturer of welders will always have to continue an experimental and service department for the benefit of his customers. Such a department, the manufacturer of the welders is constantly developing, so that what may seem impossible in welding today, may be very readily welded in sixty days to three months from this time.

WELDED JOINTS CHEAPER FOR LARGE PIPES*

The accompaning curves show the cost of fitting pipes in railroad-shop power plants, both with flange fittings, screw fittings and welded joints, based on the cost per joint, which includes cutting two threads, fitting two flanges and bolts in the case of the flange fittings, or screwing and coupling in case of the screwed fittings.



For sizes under 3½ in. the cost per joint in the case of welded pipe is a little more than the cost of screwed fittings until the smaller sizes are reached, where the two costs run about equal. For sizes 3½ in. and larger there is a material saving in cost, due to welded joints. In comparison with flanged fittings the saving is considerable for all sizes, averaging close to 50 per cent in the

*Excerpt from report of Committee on Morednization of Stationary Boiler Plants, Mechanical Division, American Railway Division, annual convention, June 14-17, Atlantic City.

1 to 6-in. sizes. However, the saving is not all in the first cost of the fittings, but by eliminating threaded joints, much longer life and less maintenance can be expected. This is especially true of long lines, such as air-distributing lines running through shops and car repair yards. The weakest point of a threaded pipe is at the threads, that is, so far as length of life is concerned. It is here that corrosion first takes place, which in a short time results in leakage of air or steam, or other contents of the pipe.

Two methods of welding pipe are suggested: One, a butt weld, in which the pipe is carefully faced on the end and in some cases scarfed; and second, a lap weld, made by using a sleeve, similar to a coupler without threads, slipped over the joint and the sleeve welded to the pipe at either end. Where the latter method is used, special fittings, such as "T's" and "L's" could be made up economically on a production basis when the demand for such fittings became sufficiently large. When the butt weld is used, great care must be taken to prevent the formation of fins inside of the pipe that obstruct the flow. With the sleeve type of weld, such obstructions are obviated and greater strength is given to the pipe at the point of the weld.

It is to be understood that no definite recommendations are made at this time for the welding of pipes. However, the possibility of saving by the use of welded instead of flanged or screwed joints is great. This applies to the smaller size pipes, 6 in. and under, where pressures are comparatively low, say not to exceed 150 lb. For power-plant work, where high-pressure headers are used, a different method of welding would have to be adopted.

CURRENT WELDING LITERATURE

TO OBTAIN COPIES OF PAPER—The Engineering Societies Library is prepared to supply copies, translations, or abstracts of any papers in the Library at the following rates:

Translations, $5.00 per 1000 words and upward by arrangement.

Photoprint copies of articles, maps, etc., 25 cents per sheet, (11 by 14 in.); typewritten copies, $1 per 1000 words.

Bibliographic searching, abstracting, etc., $2 per hour.

Communications should be addressed to: The Engineering Societies Library, 29 West Thirty-ninth Street, New York.

Arc Welding with Special Consideration of its Economy. Die Lichtbogenschweissung unter besonderer Berucksichtigung ihrer Wirtschaftlichkeit. Wintermeyer, Elektrotech Anzieger (May 18, 1922), Vol. 39, pp. 667-8.

Arc Welding, Investigation of, Quality and Uses of Electric. Qualitatsuntersuchungen und Verwendungen Elektrischer Lichtbogen-Schweissung. O. Kjellberg, Autog. Metallbearb. (May 1, 1922), Vol. 15, pp. 124-9.

Best method of Welding Safe Ends on Tubes. Committee Report before Master Boiler Makers' Association. Railway Journal, (July, 1922), Vol. 28, pp. 17-18.

Butt Welding Tubing. The Elyria Iron and Steel Co., Canad. Pat. 219127. Off. Rec., (May 30, 1922), Vol. 50, p. 1274.

Cast Iron Weld. Power, (Aug. 22, 1922), Vol. 56, p. 290. Description of a Large Successful Cast Iron Weld.

Contraction in Tube Welding, Captain D. Richardson, Welding Engineer, Vol. 7, (August, 1922), p. 1920. Distortion can be avoided by expanding pieces in the opposite sense before welding.

Electric and Magnetic Tests. T. Spooner and I. Kinnard, Welding Engineer, Vol. 7, (August, 1922). Laboratory Tests indicate that Electrical and Magnetic Tests may soon fnd commercial applications.

Electric Resistance Welded Rail Joints. E. B. Entwisle, The Electrical News, (June 15, 1922), Vol. 21, pp 62-3. Failures, Butt Weld.

Electrical Welding Applied to Steel Construction. With Special Reference to Ships. A. T. Wall, with discussion. Proc. Inst. of Mech. Engrs. (Feb. 1922), pp. 239-88.

Electric Welding Installations, Elektrische Schweissanlagen. K. Micksch, Metall Technik, (May 4, 1922), Vol. 48, pp 205-8.

Flux Coatings for Electrodes. J. B. Green, Welding Engineer, Vol. 7, p. 37-38. Some tests have been made to determine why the weld benefits from the use of Flux Coating.

The History of the Development of Electric Welding. J. M. F. Wilson, The Electrical News, (June, 1922), Vol. 31, pp 40-1. Electrode constituents, their effect. Automatic welding, position and handling of electrode, alternating current welding, operating features of A. C. Welder.

A Managerial Study of Oxy-Acetylene Cutting and Welding in Foundries. C. O. Carter, Acetylene Journal, (August, 1922), Vol. 24, pp. 86, 96 to 98, 102. Installation of equipment, holding work for cutting, operation of cutting process, cutting risers while still warm, segregating castings into sizes, speed not dependent entirely on pressure, cutting through blowholes in risers, effect of cutting on metal, welding applications.

The Oxy-Acetylene Process in Railroad Shops. F. S. Tiner, Acetylene Journal, (June, 1922), Vol. 23, pp. 604, 606, 608, 610, 619, 620, 626. Training welders, supervision, preparation for the weld, preheating, suggestions for welder, annealing, experience in welding on virginian railway, discussion.

Preheating and Welding Tables for the Oxy-Acetylene Welder. J. R. Sprague, The American Blacksmith, (June, 1922), Vol. 21, pp. 128-9.

Principles of Oxy-Acetylene Welding, Alfred S. Kinsey, Railway Mechanical Engineer, (June, 1922), Vol. 96, pp. 311-3. Manufacture of oxygen, handling of oxygen, measuring the consumption of gases, combining the gases.

Reclaiming Used Fish Plates, E. J. Shuler, Electric Traction, Vol. 18, (Aug. 1922), p. 692. Method of reclaiming fish plates by the New Orleans Railway and Light Co., 17,000 plates reclaimed in a period of six months, oxy-acetylene and Electric Arc used to do work. Cost of reclaiming.

Relationship between Physical Properties of Filler Rod and Weld Metal, J. B. Green, Acetylene Journal, (August, 1922), Vol. 24, p. 84.

Welding Duralumin—Some Experimental Work and Its Results. Horace C. Knerr, Acetylene Journal, (August, 1922, Vol. 24, pp. 63-67. Successful welds made at Naval Aircraft Factory. Butt welds, flange welds, samples prepared by welding company, tensile tests, effect of corrosion, gasoline and benzol, bend tests welded duralumin tanks, removal of welding flux, heat treatment.

Welding Marine Boilers, Acetylene Journal, Vol. 24, pp. 67-8. Rules and regulations of the Steamboat Inspection Service Department, of the Department of Commerce, governing welding and reinforcing by electric, oxy-acetylene or other processes.

Welding Sheet Aluminum. Welding Engineer, Vol. 7, (August, 1922), pp. 28-29. How an automobile body manufacturer trains welders to make perfect seams with a torch.

The American Welding Society

The American Welding Society is organized to provide united and co-operative action in extending the knowledge of the art of welding and its field of industrial application. The field for further application of welding is enormous, and progress in it is being delayed only by incomplete knowledge and by the confusing and opposing claims of competing interests.

The Society acts as a clearing house for information. Through papers and monthly meetings of local sections of the Society an opportunity is created for the individual manufacturer, engineer, plant superintendent, foreman, operator, etc., to contribute his own knowledge in welding and at the same time receive the benefit of the combined knowledge and experience of all other members of the Society Special publication in addition to the regular monthly proceedings are issued from time to time giving results of researches, standardization work and other information of value to the members.

CLASSES OF MEMBERSHIP

Extracts From By-Laws

ARTICLE I

Section 1. Individuals having received the approval of a majority of the Membership Committee shall become members of this Society upon the payment of dues, except in the case of honorary members who shall be elected by unanimous vote of the full Board of Directors.

Section 2. Membership shall be divided into five classes:

Class A. Sustaining members, being individuals or individuals delegated by corporations, firms, partnerships, etc., interested in the science and art of welding, with full rights of membership. Annual dues $100.00

Class B. Members, being individuals interested in the science and art of welding, with full rights of membership.

Engineers or individuals competent by experience or training to plan or direct welding operations are eligible to this class. Annual dues $20.00

Class C. Associate members with right to vote but *not* to hold office, except in Sections as may be provided for by the By-Laws of the Sections. Supervising welders, inspectors and skilled operators, with three or more years' practical experience in welding are also eligible to this class. Annual dues $10.00

Class D. Operating members, who are welders or cutters by occupation, without the right to vote or hold office except in Sections as may be provided for by the By-Laws of the Sections. Annual dues $5.00

Write to the Secretary for a membership blank.

Technical Bulletins

These Bulletins are published under the auspices of the American Bureau of Welding. The Bureau is a joint advisory board of the American Welding Society and the Division of Engineering of the National Research Council on welding research and standardization. It acts as the Research Department of the Society.

BULLETIN No. I

Standards for Testing Welds

These Standard Tests Comprise

(a) Shop Standard: A simple standard test for such purposes as checking the work of a welder, testing a new lot of welding wire, and testing the effect of some change in conditions.

(b) Commercial Standard: For cases where more than one kind of test should be made but where the circumstances do not justify a complete investigation.

(c) Research Standard: When a complete investigation of a weld is to be made for research or other purposes, all tests and examinations are made which will contribute any information in regard to the characteristics of the weld.

Price per copy—Members 25 cents, Non-members, 50 cents.

BULLETIN No. II

Welding Wire Specifications and Folios

The specifications and folios are based on the data collected by the Welding Wire Specifications Committee as to the chemical analysis of welding wire used for both gas and electric welding in railroads, shipyards and other places and the service results obtained from the use of such wire.

Price per copy—Members 25 cents, Non-members 50 cents.

BULLETIN No. III

Standards for Electric Arc Welding Apparatus

These rules provide Standards for use in connection with specifications for the purchase, sale and use of Arc Welding Apparatus. The rules include classification, definition of terms, information relative to apparatus to be supplied by the prospective supplier and by the prospective purchaser, respectively, and tests. Price per copy: Members 15c, Non-members 30c.

Take the GUESS WORK Out of Welding

IN YOUR PLANT there is a man who needs timely and accurate information about welding. He should know what is being done in other plants to reduce costs and increase efficiency. No matter what your welding problem may be, The Welding Engineer is the best scource of information, the best adviser you could have. Every phase of welding, both manufacturing and repair problems, is discussed fully in this valuable monthly publication. The best authorities in America on the subject of welding are regular contributors.

Every process of welding is discussed by The Welding Engineer. Arc Welding, Electric Butt, Spott and Seam Welding, Oxy-Acetylene and the Thermit System, in fact every known process of joining metals is discussed. Its Buyers' Index reflects the progressiveness of America's first manufacturers.

L. B. MACKENZIE, Editor H. S. CARD, Associate Editor

Price $3.00 In The United States And Canada, $4.00 Abroad.

Write for free sample copy for convincing proof that The Welding Engineer is indispensable in your business.

Member Audit Bureau of Circulations

The Welding Engineer

Member Associated Business Papers, Inc.

608 S. DEARBORN STREET, CHICAGO

THE GAS WELDERS MONTHLY MAGAZINE

Acetylene Journal

Every day brings new information on the subject of gas welding. New uses for the torch, business-building kinks devised by shop proprietors and a hundred other things which help the welder.

Oxy-acetylene welding has its own publication in the ACETLYENE JOURNAL. All the news and developments of the day appear in its columns in the shape of helpful illustrated articles, news items and contributions by the "other fellow" which are helpful to you.

Several thousand welders read the Journal. Your name shou'd be on our list. Just send in your name, address and a one dollar bill ($1.00 per year in U. S. and Canada; $1.50 abroad) and you will insure a years interesting and profitable reading on YOUR trade.

Write for a sample copy for convicing proof that the Journal is indispensable to your business.

H. W. COOK, EDITOR

ACETYLENE JOURNAL

122 So. MICHIGAN AVENUE CHICAGO, ILL.

All books on welding may also be obtained through this office, including the famous "Autogenous Welding" by Granjon & Rosemberg (price $3.00) for which this office has the exclusive American rights.

ACETYLENE FROM CAKES

The most modern, efficient and safest source of acetylene supply—Carbic CAKES

Not an experiment. Hundreds of Carbic generators using Carbic arc in daily use on all kinds of welding and cutting work.

The use of Carbic Cakes permits an ease of handling, a convenience and a safety not otherwise obtainable.

Acetylene from Carbic costs but one-half as much as compressed acetylene and only a few drums of cakes carried in stock insure a large supply of gas on hand at all times.

Carbic low pressure, portable generator. Weight charged—200 lbs. Listed as standard by Fire Underwriters' Laboratories.

You should know ALL the Carbic advantages. Write us for full information.

The Carbic line is complete, including generators, torches, regulators, etc.

THE Carbic SYSTEM

Carbic Cakes are packed in sheet metal drums and will last indefinitely. Stocks carried in principal cities.

CARBIC MANUFACTURING CO.

DULUTH, MINN.

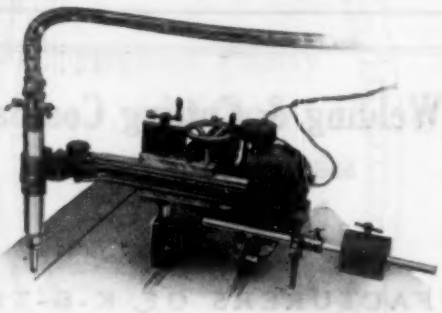
New York, 141-149 Center St. Boston, 27 School St. Chicago, 565 W. Wash. Blvd

Warehouses and Representatives in other principal Cities.

AIRCO
DAVIS
APPARATUS

ANYTHING AND EVERYTHING
For Oxyacetylene Welding and Cutting

SERVICE



ECONOMY

AIRCO-DAVIS-BOURNONVILLE RADIAGRAPH

The Radiagraph, Oxygraph, Camograph and Pyrograph are some of the exclusive machines designed by Airco-Davis-Bournonville experts for mechanical cutting of steel plates, forgings, dies, etc.

The Radiagraph provides greatly increased production and reduced operating costs in fabricating plants, steel mills, boiler shops, bridge works, and locomotive and car-shops. The Airco Consulting Engineering Staff will be glad to point out the advantages of specially designed machinery for mechanical cutting and welding.

Special Bulletin, illustrating and describing mechanical cutting on production work, will be sent on request.

Write for Airco Booklet:
"Anything and Everything for Oxyacetylene Welding and Cutting"

AIR REDUCTION SALES COMPANY
Manufacturer of Airco and
Airco-Davis-Bournonville Products
Controls the manufacture and sale of National Carbide
Home Office: 342 Madison Ave., New York, N. Y.

Airco District Offices, Plants and Distributing Stations conveniently located throughout the Country.

"Airco Oxygen and Acetylene Service is Good Service."

JOB WELDERS ATTENTION!

YOU DON'T NEED CAPITAL!

Bring Your Shop Up-to-date With an Electric Arc Welder, Motors and Other Electric Appliances. Inquire Regarding Our Monthly Payments. **PAY WHILE YOU EARN.**

Rego Apparatus
Armco Welding Wire

WELDING SERVICE CO.
30 Church Street, **New York City**

K-G Welding & Cutting Company, Inc.

556 WEST 34th STREET

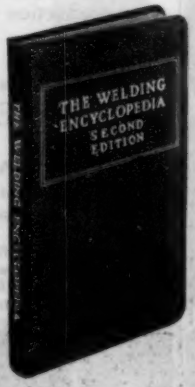
New York City

MANUFACTURERS OF K-G-TORCHES

NEW EDITION OF WELDING ENCYCLOPEDIA READY FOR DISTRIBUTION

The regular retail price of this book is $5.00. A special price of $3.00 has been made to the members of the American Welding Society if the order is placed through the office of this society. No reduction in price will be made on orders received directly from the subscriber.

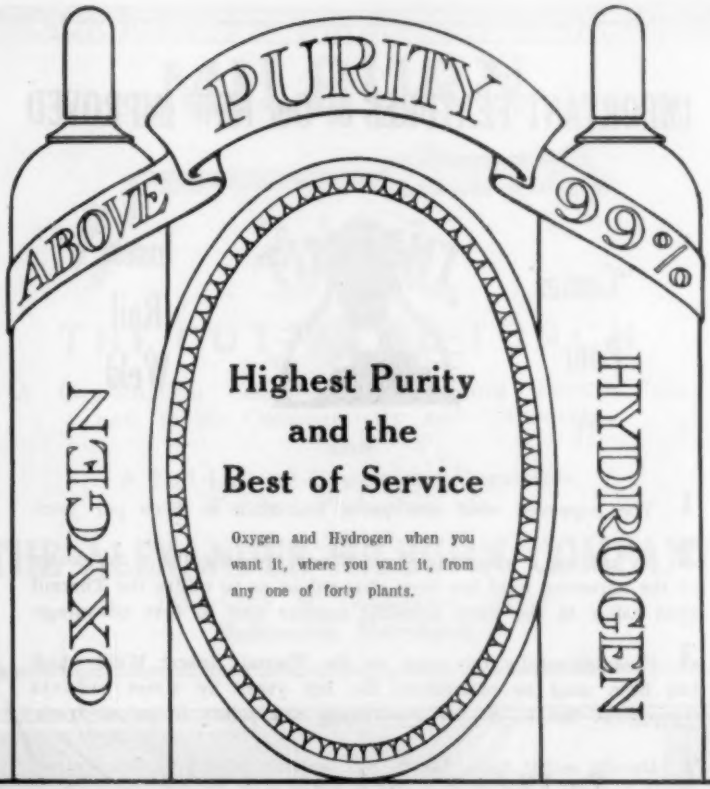
The book this year will be bound in imitation flexible leather with gilt edges and contains about 100 additional pages. The new edition has been thoroughly revised and brought up to date.



Send order to

AMERICAN WELDING SOCIETY

33 West 39th Street, New York, N. Y.


ABOVE PURITY 99%
OXYGEN
HYDROGEN
Highest Purity and the Best of Service
Oxygen and Hydrogen when you want it, where you want it, from any one of forty plants.

ELECTROLYTIC PLANTS EVERYWHERE

CALIFORNIA
California Compressed Gas Co., Los Angeles
California Compressed Gas Co., Oakland

COLORADO
Colorado Compressed Gas Co. Denver

ILLINOIS
Acme Oxygen Co., Chicago
Burdett Oxygen & Hydrogen Co., Chicago
Electrox Co., Peoria
National Oxygen Co., Chicago
Swift & Co., Chicago

INDIANA
Indiana Oxygen Co., Indianapolis
Logansport Oxygen Co., Logansport

IOWA
Bettendorf Oxygen Hydrogen Co., Bettendorf

KENTUCKY
Kentucky Oxygen & Hydrogen Co., Louisville

LOUISIANA
Louisiana Oxygen Co., Inc., New Orleans

MANITOBA
Auto-Lite Gas Co., Ltd., Winnipeg

MICHIGAN
Burdett Oxygen Co., of Detroit, Detroit
Michigan Ox-Hydric Co., Muskegon
National Oxygen & Machinery Co., Detroit

MINNESOTA
Commercial Gas Co., Minneapolis

MISSOURI
Kansas City Oxygen Gas Co., Kansas City (two plants in Kansas City)
St. Louis Oxygen Co., St. Louis

MONTANA
Mountaineer Welders' Supply Co., Butte

NEBRASKA
The Baibach Co., Omaha

OHIO
Clarke Chemical Co., Wickliffe
Ohio Electrolytic Oxygen Co., Cincinnati

OKLAHOMA
Burdett Oxygen Co., of Oklahoma, Oklahoma City
Tulsa Oxy-Hydro Co., Tulsa

OREGON
Portland Oxygen & Hydrogen Co., Portland

PENNSYLVANIA
Burdett Oxygen Co., Philadelphia (plants at Chester and Norristown)
Burdett Oxygen & Hydrogen Co., Pittsburgh, Pa.
National Oxygen Co., Erie

TENNESSEE
Burdett Oxygen Co., Chattanooga
Memphis Oxygen Co., Memphis

TEXAS
Burdett Oxygen Co., of Texas, Fort Worth
Magnolia Gas Products Co., Houston

UTAH
Utah Compressed Gas Co., Salt Lake City

WASHINGTON
Washington Compressed Gas Co., Seattle

WISCONSIN
Universal Oxygen Co., Sheboygan
Wisconsin Oxygen & Hydrogen Co., Kenosha

GAS PRODUCTS ASSOCIATION

140 S. DEARBORN CHICAGO, ILL.

IMPORTANT FEATURES of Our NEW IMPROVED

"Center Pour"

Insert Rail Weld

1 The improved weld now saves you $2.00 to $3.00 per joint.

2 By making a great many welds and breaking them, the design of the improved weld has been changed so as to utilize the Thermit steel collar in the most scientific manner and to best advantage.

3 Foundamentally the same as the Thermit Insert Weld which has been used so extensively for ten years by street railways throughout the U. S. for eliminating rail joints in paved track.

4 During recent tests, 134 lb. rail sections welded by this method finally broke outside of the weld in every test.

5 When installed in conjunction with our improved Thermit rail welding appliances, there should be no trouble in welding 20 to 25 joints per day if four men and one preheater are used, or about 40 joints per day, using six men and two preheaters.

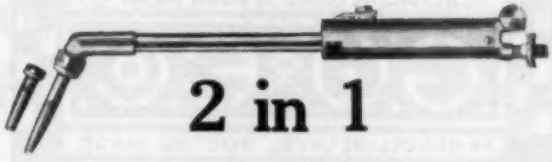
Tell us the section number of your rail so we can quote you on suitable welding material. We will also be glad to send you an expert demonstrator to show you how economical the improved Thermit Insert Weld is.

METAL & THERMIT CORPORATION

120 Broadway, New York

Boston Pittsburgh Chicago S. San Francisco Toronto

MILBURN



2 in 1

THE CUT-WELD TORCH

A Combination Cutting and Welding Torch, Cuts and Welds Commercially and Efficiently

also

A Full Line of Generators, Regulators, Torches, Preheaters, etc.

THE ALEXANDER MILBURN COMPANY

1420-1428 W. Baltimore Street

Baltimore, Maryland.

Insulation

HAZARD "LORECA" ARC-WELDING CABLE

THE INSULATION on the conductor which carries the welding current, performs a most important function.

It must be extremely tough and elastic to withstand the rough handling and must be an efficient insulator in order to confine the current to the conductor.

HAZARD LORECA Welding Cable is designed especially for work of this kind and will outlast three to ten of the ordinary cables.

Hazard Manufacturing Co.

WILKES BARRE, PENNSYLVANIA

HAZARD LORECA WELDING CABLE (Patented)

NEW YORK PITTSBURGH CHICAGO DENVER BIRMINGHAM

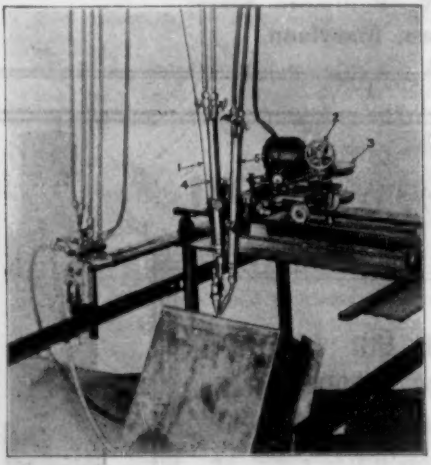
GENERAL WELDING & EQUIPMENT CO.

G.W.&E.C.

74 BROOKLINE AVE., BOSTON, MASS.

"GEWE" AUTOMATIC WELDING MACHINES

— METAL WELDING REVOLUTIONIZED —



A WONDERFUL BEAD BOTH FORGED AND FUSED WITHOUT THE AID OF EXPERTS.

SEWED TOGETHER BY SPIRAL LAYERS OF PARTLY MOLTEN, PARTLY FORGED-IN METAL WIRE.

This machine has a pre-heating torch (No. 5) as well as the self-feeding torch (No. 4), which latter osciliates in circles or ellipses through an independent ex-center movement driven sprocket wheel (No. 2). The torch (No. 5) preheats the seam to very near the fusion point and is followed closely by torch carrying the added material. The latter covers enough surface so as to melt not only the seam proper, but also both sides of the seam, spreading the added material over the same area and melting and forging it in at the same time. The progressive movement is adjustable with friction wheel and disc (No. 3).

Welding rod (No.1) is fed in by gravity passing through centre of multiple flame tip of torch (No. 4). It forges itself in vertically by its weight and laterally by the spiral movement of torch (No. 4). The welded area is protected from outside air by the encircling multiple flames. Every part of the operation is independently adjustable.

SIMPLE, EFFICIENT, REASONABLE

Acetylene in Portable Cylinders for Oxy-Acetylene Welding and Cutting

Supplied in any quantities. Do you understand our free loan plan? If not, we are glad to explain.

Supplied in the following sized cylinders:

10″ x 30″ size—capacity approx. 125 cu. ft.
12″ x 36″ size—capacity approx. 225 cu. ft.
12″ x 44″ size—capacity approx. 275 cu. ft.

Prompt and efficient service through plants and warehouses.

Commercial Acetylene Supply Co., Inc.

(Main Office) 80 BROADWAY, NEW YORK CITY

BRANCHES:—

204 Trust Co. of Ga. Bldg., Atlanta, Ga.
540 So. Dearborn St., Chicago, Ill.
553 Monadnock Bldg., San Francisco, Cal.
18 Toronto St., Toronto, Ont., Canada.

USUALLY **CARBIDE MEANS**
UNION CARBIDE

It always does at 150 *Union Carbide warehouses,* strategically located from Portland, Maine, to San Diego, California, and from Seattle on Puget Sound to Tampa on the Gulf.

Union Carbide is always packed in blue-and-gray drums.

UNION CARBIDE SALES COMPANY
Carbide and Carbon Building—30 East 42nd St.
NEW YORK CITY

CHICAGO
Peoples Gas Bldg.

SAN FRANCISCO
Balfour Bldg.

Service That Carries On

LINDE is vitally interested in aiding oxygen users.

The *will to help* is futile if it is not combined with the *ability to serve.* In a nation-wide business such as the Oxygen Industry, ability to serve depends on physical facilities and organization.

84
Linde
Plants
and
Warehouses

Linde Service only *begins* with seeing that your oxygen supply requirements, wherever you may be, are satisfied promptly and fully. It carries on—extends real co-operation and constructive advice as to the efficient and economical use of oxygen. *It belongs to Linde users.*

THE LINDE AIR PRODUCTS COMPANY
Carbide and Carbon Bldg., 30 East 42nd St.
New York
Balfour Building, San Francisco.

PREST-O-LITE PRE-EMINENCE

THE result of sincere, unceasing effort, backed by the essentials of success, to establish and maintain purity of product and dependability of service, available *always* where there exist demands for dissolved acetylene--54 plants and warehouses *at your service*

Pittsburgh
Buffalo
Milwaukee
Chicago
Cleveland
Atlanta

Prest-O-Lite
DISSOLVED ACETYLENE

San Francisco
Dallas
Philadelphia
St. Louis
Boston
Detroit

THE PREST-O-LITE COMPANY, INC.
General Offices: Carbide and Carbon Building, 30 East 42nd Street.
New York
ADDRESS ANY DISTRICT SALES OFFICE LISTED ABOVE

Oxweld Can Do It!

A Slogan Built on Performance

OXWELD ACETYLENE COMPANY

NEWARK, N. J.
CHICAGO
SAN FRANCISCO

WORLD'S LARGEST MAKERS OF OXY-ACETYLENE EQUIPMENT

A GOOD BOND

By A Direct Weld of Copper to Rail

Electrical requirements have made copper the almost universal bond material. To weld this copper bond direct to the rail quickly and positively was made possible by the RWB Carbon Arc Process.

The arc really never touches the rail, but is merely the source of heat that melts the original bond terminal into the weld itself and the weld seals it to the rail.

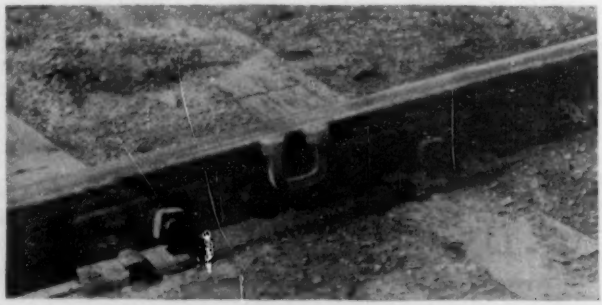
A special Alloy Filler Wire is used to produce bond heads, practically free from porosity and to increase the strength of the contact between the copper and steel.

From 25,000 to 32,000 pounds per square inch is necessary to shear the bond from the rail. This assures long life against the wear and tear of traffic conditions.

The electrical conductivity of RWB Bonds is very high as the path of the current is copper from rail to rail. The bond head itself has less than 5% of the whole bond resistance.

The RWB line of bonds is complete. This includes both the cable and laminated types as requirements may demand. They can be supplied in any standard carrying capacities.

This latest bond development will be demonstrated at our booths No 51 and 52 at the Chicago Convention. Send for Bulletin No. 102, RWB UNA Bonds and Bulletin No. 101, which tells how a Type BB Dynamotor can save money for you the year around.



RAIL WELDING & BONDING CO.

CLEVELAND, OHIO

A GOOD JOINT

Adds Years of Life to Your Rails

RWB Carbon Arc Welded Joints have reclaimed many hundreds of miles of old track. The saving in time and money in this manner has lead one prominent maintenance of way engineer to state that he considered this process one of the greatest contributions in solving the problem of track maintenance.

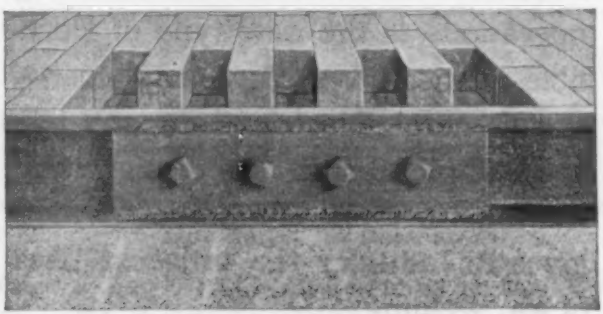
It is a well known and accepted fact that rail joints determine to a large extent the life of a track. It is, therefore, exceedingly important to guard against deterioration of the joints in order to preserve the rails and give the entire track long life, with a minimum amount of maintenance.

The RWB Carbon Arc Welded Joint meets these requirements in an admirable way and in addition costs less than any other type of joint used in paved right of ways.

The same RWB Dynamotor which supplies the Carbon Arc Welding current for installing the joints is also a metallic arc welding unit. This provides for building up worn and cupped rails and repairing manganese special work so that complete rehabilitation of old track can be accomplished.

Full description of the Carbon Arc Process of welding joints and how the Type WW Dynamotor is used not only for track work, but for shop welding is given in a recent catalogue. It is yours upon request.

Visit our booths No. 51 and 52 at the Chicago Convention.



RAIL WELDING & BONDING CO.
CLEVELAND, OHIO

G-E Portable Semi-Automatic Arc Welding Equipment is the most advanced method of arc welding.

ACHIEVEMENT

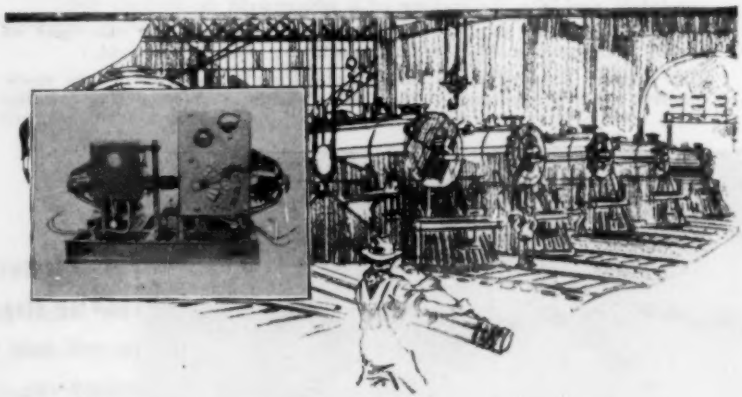
From the first sets for hand welding operations to the new type of Portable Semi-Automatic Arc Welder—the General Electric Company has been a pioneer in the design and manufacture of equipment which gives to Industry the broadest uses of arc welding.

General Electric Company

General Office Schenectady, N.Y.

Sales Offices in all large cities 438-651X

If electric arc welding had been employed twenty years ago, the junk piles of manufacturers would not occupy valuable real estate today



Putting New Mileage Into Old Locomotives

Many broken or worn locomotive parts are being rebuilt and made as good as new through the use of electric arc welding. One railroad alone has replaced in service, with a **minimum delay**, several hundred locomotives—making repairs by this modern process.

This is one of the big applications of electric arc welding, but it is just as valuable in industries where the product is not so ponderous. Automobile parts, tanks, plumbing fixtures, metal furniture, doors, partitions, window sash, in fact many metal products which must be permanently joined—offer most profitable applications for electric arc welding.

Strength, durability, speedy production, low cost of operation—these are some of the qualifications of electric arc welding in the average factory.

G-E arc welding sets embrace many types—from the portable single-operator to the big multi-operator, stationary sets or the speedy production automatic type. And G-E experience includes the knowledge necessary to apply the proper set to the particular job.

Select the right equipment for the work—and a welder who knows his business

Bulletins describing G-E Welding Equipment and the G-E Welding School sent on request to our nearest office

General Electric Company

General Office Schenectady, N.Y.

Sales Offices in all large cities

SLAGLESS WELDS

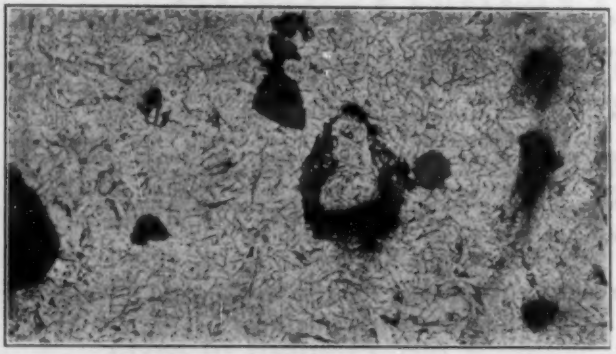
Slag in welds is the direct result of slag or slag-forming ingredients in the welding material.

Slag prevents the grains of the metal from becoming united, which absolutely prohibits the making of a sound weld.

A weld free from slag or non-metallic inclusions is one assurance of a solid homogeneous deposit and therefore a *dependable* weld.

Page-Armco Welding Rods and Electrodes are the purest iron made (99.84% iron guaranteed). They are free from slag or slag-forming

Photomicrograph showing slag in gas weld made with ordinary wire.



Photomicrograph showing slag in electric weld made with ordinary wire.

STEEL AND WIRE PAGE QUALITY PRODUCTS

PAGE STEEL

BRIDGEPORT

District Sales Offices: Chicago, New York

PAGE-ARMCO

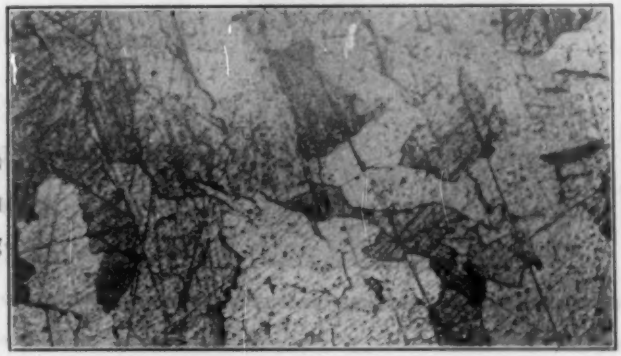
WELDING RODS AND ELECTRODES

ingredients and fulfill every requirement of *dependable* welding material.

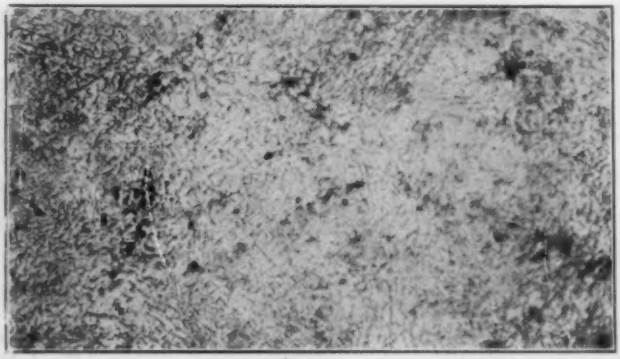
They conform in all respects to
American Welding Society Specifications for

Electrodes	E-No. 1-A
Gas Welding Rods	G-No. 1-A

Yellow tag denotes Gas Welding Rods. Ends of rods colored yellow.
Blue tag denotes Electrodes. Ends of rods colored blue



Photomicrograph showing slagless gas weld made with Page-Armco Welding Wire.



Photomicrograph showing slagless electric weld made with Page-Armco Welding Wire.

& WIRE CO.

CONNECTICUT

Pittsburgh, Portland Ore., San Francisco

ARMCO

INGOT IRON

"ALTERNARC"

Better, Faster and Cheaper Welding
Greater Flexibility and Convenience

Alternarc Welding has every advantage in producing good welds, at a faster rate of speed and at lower cost. Most flexible in application.

Ask About the "Alternarc"

Electric Arc Cutting & Welding Co.

152 Jelliff Ave.

NEWARK, N. J.

ROEBLING WELDING WIRE

Electric Welding

For

Oxy-Acetylene (Gas) Welding

JOHN A. ROEBLING'S SONS CO

TRENTON, NEW JERSEY

Branch Stores and Warehouses

New York Boston Chicago Philadelphia Pittsburgh Cleveland Atlanta San Fransisco Los Angeles Seattle Portland, Ore.

ELECTRIC ARC WELDING SETS

Self Contained—Requiring No Exciter.
Current Accurately Adjustable—
Moderate Speed Insuring Long Life.

WE INVITE INQUIRIES

Our Engineers Will Assist You in Determining What is Best Suited for Your Needs.

BURKE ELECTRIC CO.

Manufacturers of
ELECTRIC WELDING OUTFITS
and
ELECTRIC MOTORS AND GENERATORS
FOR ALL PURPOSES.

Main Office and Works, Erie, Pa.

Service-Sales Offices

New York *Detroit* *Philadelphia*
Pittsburgh *Cleveland* *Buffalo*

AIRCO

DAVIS APPARATUS

ANYTHING AND EVERYTHING

For Oxyacetylene Welding and Cutting

SERVICE

AIRCO OXYGEN
AIRCO ACETYLENE

The Air Reduction Sales Company is the largest manufacturer and distributor of a complete line of gases, apparatus, supplies and specially designed machines for oxyacetylene welding and cutting.

Two of the most important units in the comprehensive list of Airco and Airco-Davis-Bournonville products are Airco Oxygen and Airco Acetylene.

Specifying "Airco" when ordering oxygen or acetylene is simply expressing confidence in a time-tested standard of excellence.

Supporting this standard are two business-building essentials.

First, a carefully-planned, nation-wide system of plant and warehouse distribution which insures up-to-the-minute deliveries for either steady or emergency consumption.

Second, the specialized engineering skill of an Advisory Service Staff which offers to all industry constructive solutions of welding and cutting problems.

SERVICE

Write for Airco Booklet:

"Anything and Everything for Oxyacetylene Welding and Cutting"

AIR REDUCTION SALES COMPANY

Manufacturer of Airco and Airco-Davis-Bournonville Products

Controls the manufacture and sale of National Carbide

Home Office: 342 Madison Ave., New York, N. Y.

Airco District Offices, Plants and Distributing Stations conveniently located throughout the Country.

"Airco Oxygen and Acetylene Service is Good Service."